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NOTICE

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of contributions within its field, but such publication is not to be construed as official approval of the views expressed.

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II. Tracks of centers of anticyclones.
III. Tracks of centers of cyclones.
IV. Percentage of clear sky.
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CORRECTIONS AND ADDITIONS

VOLUME 37, NOVEMBER, 1909

Page 954: Last column, the total precipitation for Fallon, Nevada, recorded "7.10" inches, should be "0.71" inch.

VOLUME 50, DECEMBER, 1922

Page 666: The average precipitation for North Dakota, recorded as "0.57" inch, should be "0.67" inch.

VOLUME 57, DECEMBER, 1929

Page 529: In the first column, second paragraph from the bottom, third line of the "NOTE," omit the minus sign before "56.7 C."

VOLUME 59, JANUARY, 1931

Page 31: Second column, twenty-fourth line from top, change "a" thousand feet to "two or three" thousand feet.

VOLUME 59, MARCH, 1931

Page 98: Table 1, column headed "Caspian Sea," first entry, "High 1838," should be "High, 1638."

VOLUME 59, MARCH, 1931—Continued

Page 103: Figure 6, bottom line, in the last two last squares, "A3=16″=7.74", the "7.74" should be "6.74," and in the next column "6.38" should be "6.08."

VOLUME 59, JUNE, 1931

Page 219: The correct title of the article on this page is, "Ground Plan of a Dynamic Climatology."

Page 228: The illustration marked "Figure 8" should read "Figure 5.—Distribution of wreckage at the Quinn Ranch at the mouth of Tree Canyon, about 6 miles southwest of Gothenburg." The three tornado illustrations on the opposite page should bear the numbers "6," "7," and "8," respectively. The legend to Figure 6 should read, "Funnel dropping on Quinn Ranch at Tree Canyon, 5 miles southwest of Gothenburg. Photograph taken from a point one-half to three-quarters of a mile east of the funnel, by Mrs. Roy Homer." The other two legends are correct, except that the numbers should be "7" and "8," respectively.

VOLUME 59, OCTOBER, 1931

Page 402: In the table headline "September" should be "October."

SUBJECT AND AUTHOR INDEX OF THE MONTHLY WEATHER REVIEW, 1931. VOL. 59

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MONTHLY WEATHER REVIEW

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THE EVOLUTION OF METEOROLOGICAL INSTITUTIONS IN THE UNITED STATES

By Eric R. Miller

[Weather Bureau, Madison, Wis.]

The object of this paper is to outline the stages in the growth of the organizations that have dealt with climate and weather in the United States of America and to present a chronological bibliography.

It should be noted that there has been mutual reaction of the growing institutions and the growing science of meteorology. The invention of the electric telegraph, after institutions and science were well founded, acted as a powerful catalyst, enabling the science to be effectively applied to the forecasting of storms and weather.

The settlement of the continent, gradually pushing the frontier westward, widened the field of observation. The Civil War marks an important turning point, from financial stringency to post-war inflation, which accounts for the diffusion of meteorological work among many institutions where it was scantily supported by eking out small sums from budgets intended for other purposes, before the war, and then afterward the quick development of a single relatively lavishly supplied institution.

Sir Napier Shaw (**68**, p. 1) argues that the change from horseback and stage coach to railways and from sailing vessels to steamers, as well as improvements in dwellings and clothing, caused people to lose interest in weather and to relegate it to institutions. On the other hand, is it not true that the size of atmospheric phenomena bars them from the scope of individuals, and even of institutions, like universities, that lack country-wide extent?

1753: In colonial times the only country-wide organization was the Post Office. Benjamin Franklin, appointed Postmaster-General of the Colonies, 1753, used his contacts with postmasters and shipmasters for research on progression of cyclones, and ocean currents (**47**, pp. 488–490), but his manner of publication nearly cost him all credit (**58**).

On April 2, 1814, amidst the war of 1812, James Tilton (1745–1822), revolutionary patriot, member of the Continental Congress, then Physician and Surgeon-General of the Army, directed hospital surgeons to record the weather (**49j**), (**1**). This was forgotten in the larger development of meteorological work that followed reorganization of the Army, April 14, 1818, by Secretary of War Calhoun, for whom the credit was claimed (**27**). The several chiefs of the Army Medical Department, who directed its meteorological service, were (**57**):

1813–1815. James Tilton, M. D. Physician and Surgeon-General.

1818–1836. Joseph Lovell, M. D., Surgeon-General.

1836–1861. Col. Thomas Lawson, M. D., Surgeon-General.

1861–1862. Col. C. A. Finley, M. D., Surgeon-General.

1862–1864. Brig. Gen. W. A. Hammond, M. D., Surgeon-General.

1864–1882. Brig. Gen. J. K. Barnes, M. D., Surgeon-General.

The Army Medical observations are especially valuable because they are the earliest available in the West. Long series of records were kept at a few fixed stations, but many posts were occupied for only a few years until the advance of the frontier carried them westward again. The meteorological organization terminated June 19, 1874, after which post surgeons sent their meteorological reports direct to the Signal Service and Weather Bureau. The results were published in four volumes (**2**), (**8**), (**21**), (**22**), and these were the basis of the climatologies of Forry (**12**) and Blodget (**25**).

The Surgeon-General's office cooperated with Espy's service, with the Smithsonian even to changing instruments and hours of observation (**16**, 1849, p. 14), with Paine in starting the meteorological work of the Signal Service (**32**), and with Myer in organizing that work (**33**, 1870).

1817: Josiah Meigs (1757–1822), Commissioner of the General Land Office, Interior Department (previously lawyer in Bermuda defending American vessels captured by privateers, professor of natural philosophy at Yale, acting president University of Georgia), asked money from Congress to equip land offices with barometers, etc. (**46**), (**49g**). Denied this aid, his bureau undertook a modest program of observations. The results, deposited with Meigs' papers in the American Institute of New York City, were placed in the New York Public Library, October, 1928.

1817: Heinrich Wilhelm Brandes (1777–1834), German meteorologist and mathematician, drew weather maps, invented isobars (1820), (isotherms had already been invented by Humboldt (**68**, pp. 260–261, 298)), discovered cyclonic wind circulation, rediscovered progression of cyclones, and proposed a meteorological service for the study of storms (**59** pp. 45–51), (**68**, p. 299), thus antedating many later claimants for these honors.

1825: Simeon DeWitt (1756–1834), Vice Chancellor of the University of the State of New York, previously Chief Topographic Engineer on Staff of General Washington in Revolution, also Surveyor General of New York, procured a grant from the state legislature, and organized meteorological observations at the Academies operated throughout the state by the Regents. Results were published in two volumes (**23**), (**36**), design and exposure of instruments studied. Joseph Henry (**39**), (**52c**) and James H. Coffin (**52a**) were trained in the New York service. Cooperated with Smithsonian from 1849 (**16**, 1849, p. 14). Appropriations ceased, 1863, and service mostly discontinued, on account of the Civil War.

1828: Heinrich Wilhelm Dove (1803–1879) and William C. Redfield (1789–1857) started debate on theory of tropical cyclones that afterward involved Espy and Loomis and led to important advances (**44**), (**68**, p. 296).

1834: James Pollard Espy (1785–1860), (**52b**), chairman of a joint committee of the American Philosophical Society and the Franklin Institute, of Philadelphia, established a net of observation stations to study storms. Four reports (**3**), (**31**) and numerous climatic tables were published. A weather map of the storm of June 19, 1836, in third report, based on observations at 18 stations scattered from Massachusetts to Ohio, shows the storm by wind directions only. The storm of March 16, 17, 18, 1838, in the fourth report, represented by a weather map based on observations at 50 stations covering the states east of the Mississippi, is shown by wind arrows, weather, and barometer readings, entered at each station, and by circles drawn around the centers of lowest pressure, at 12-hour intervals.

The committee obtained an appropriation of $4,000 from the Pennsylvania legislature (Laws of Pennsylvania, 1837, p. 73) to equip an observer in each county with barometer, thermometers, and rain gage. This quota of one observer per county, set up in 1837 as a goal to be attained, now stands as a limit that it is prohibited to exceed, act of August 30, 1890 (26 Stat. 371, 398.)

April 20, 1838; The first appearance of meteorology in the records of Congress is a memorial from the Pennsylvania Lyceum, instigated by Espy's committee, asking a national weather service (**4**).

December 18, 1838, Espy himself asked the Senate to offer awards in proportion to the result for rainmaking by burning woodlands (**5**).

December 20, 1839, the American Philosophical Society transmitted the request of the Royal Society, London, for cooperation with James Clark Ross's Antarctic Expedition by establishing five meteorological and magnetic observatories (**6**). John Quincy Adams (**37**, v. 10, pp. 211, 306), to whose committee this was referred, tried to attach these abservatories to the survey of the northeastern boundary, but was voted down (**7**). Philadelphians supplied one observatory, at Girard College, with aid from the Topographical Engineers, United States Army (**17**).

1840: Elias Loomis (1811–1889), professor of mathematics and natural philosophy, Western Reserve College, Hudson, Ohio, published an important paper on storms (**9**) in which progressive movement was shown by mapping the trough line on successive days, a method afterward adhered to by Espy (**16** 1859, pp. 108–111). A second paper (**13**) shows the storm by isobars and isotherms, essentially as in present-day weather maps. Inasmuch as Brandes described but did not publish his isobaric maps of 1820, Loomis is entitled to great credit (**45**), (**59**), (**68**).

1840: Espy visited England and France to present memoirs to the British Association for the Advancement of Science and the French Academy of Sciences (**10**), where Arago, in his speech of introduction, bracketed Espy with Ampere and Newton.

1841: Espy's Philosophy of Storms (**11**) published, bringing convection and thermodynamics of moist air into meteorological science with their proper weight.

January 6, 1842: Espy appeared in Washington, determined to make a place for himself as national meteorologist. J. A. Adams, chairman of the Congressional committee on the Smithson bequest, records the interview in which Espy sought to have that bequest devoted to a national weather service with Espy as chief (**37**, v. 10, p. 65, v. 11, p. 52). Espy approached other influential politicians and secured a place as Professor of Mathematics, Depot of Charts, Navy Department (the germ of the present Naval Observatory and Hydrographic Office) which he held from May 7, 1842 to July 5, 1845, and another as clerk at $2,000 per annum in the Surgeon General's office beginning August 26, 1842. The item of $3,000 for meteorological work inserted by Senator Preston, of South Carolina, in the Army Bill (Act of August 23, 1842) had not created a position, hence Espy was soon attacked by watchdogs of the Treasury (**56**), pp. 507–511, but Espy enlisted powerful friends, including John Q. Adams, Jefferson Davis, Alexander H. Stephens (**40**), (**61**, p. 45), (**33**, 1883, pp. 586–588), whose tactics of inserting a rider in one appropriation bill after another, Army, Civil and Diplomatic, Naval, Legislative, Executive and Judicial, sufficed to afford him a salary of $2,000 every year until June 30, 1859 (**56**, p. 608), although Senator Pearce, of Maryland, was obliged to threaten a filibuster in the closing hours of the session to get it through on one occasion, and it was forgotten and the fiscal year 1847–48 not covered until 1852. Espy also applied his knowledge of air currents to the invention of a ventilator, which the Twenty-ninth Congress had him install on the chambers of both houses at not to exceed $250 each, and a relief bill to pay him $10,000 for the use of his ventilators on naval vessels appeared session after session.

Espy expanded the observing net that he had organized at Philadelphia in 1834 to a corps of 110 in 1842 and 1843, 50 having barometers. Increase A. Lapham became Espy's observer at Milwaukee, and his papers show daily observations tabulated on printed forms, mailed at the end of each month. These were addressed to the Surgeon General's office until August, 1849, afterward to the Navy Department. The printed forms of the Smithsonian were used beginning 1853. Espy and assistant, paid from his $2,000, extracted data, plotted them on daily weather maps, and returned the reports to the observers. Selected maps, graphs of the march of the barometer, and generalizations of the laws of storms, afforded material for four reports (**14**), (**20**), (**26**), the last of which had the distinction of being submitted to Congress as a Presidential message.

Espy and Henry had been fellow members of the American Philosophical Society at Philadelphia and came into close relations after Henry came to Washington as Secretary of the Smithsonian Institution in 1846. Espy and Loomis wrote letters in support of the meteorological part of Henry's program for the Institution (**18**); Espy signed with Henry a joint circular soliciting observers (**16**, 1851, p. 68); Espy enjoyed laboratory facilities at the Smithsonian (**26**). On the other hand, Henry procured an order from the Secretary of the Navy directing Espy to cooperate with the Smithsonian (**16**, 1848, p. 29) and claims that Espy was directed to apply to him for instructions (**16**, 1849, p. 14), and he was much interested in Espy's appropriation (**16**, 1849, p. 14), (**56**). However, the tenor of Espy's reports and of Bache's eulogy on Espy (**16**, 1859, p. 108–111) indicate that Espy attached little importance to such restrictions. The claim of Assistant Secretary Goode that "the memoirs of Professor James P. Espy on meteorology * * * were all prepared as part of the Smithsonian meteorological work" (**54**, p. 496) is discounted by the reports themselves. The first report was published and the material of the second and third, was gathered before the Smithsonian was organized. Espy's generalizations supplied one of the arguments for the memorial of Lapham (**32**) that finally resulted in the establishment of a national weather service 10 years after Espy's death.

July 1, 1842, Matthew Fontaine Maury (1806–1873) was assigned to charge of the Depot of Charts (Depot of Charts, 1830–1844; Naval or National Observatory,

1844–1854; Naval Observatory and Hydrographic Office, 1854–1866; Hydrographic Office separated, 1866) (**49b**), and began to collect and summarize ship's log-books, "Wind and Current Charts," published beginning 1846; organized International Marine Meteorological Conference, Brussels, 1853; published "Physical Geography of the Sea," first edition, 1854, fifteenth, 1874; proposed to collect weather observations from farmers as he had from sailors, and Senator Harlan introduced a bill to enable him to do so, 1856 (**24**). Maury's wind and current charts enabled merchant sailing vessels to shorten voyages and were highly appreciated by merchants and underwriters. Those of New York City presented him a $5,000 silver service, 1853, and foreign potentates showered upon him medals and orders of nobility. He was elected to 45 learned societies, 20 foreign. He was not appreciated by his superior officials, who sought to retire him. He resigned, 1861, to throw in his lot with the Confederacy (**43**), (**69**), (**70**), (**71**).

1844. Morse and Vail demonstrated electric telegraph (**52e**), Washington-Baltimore, and established first commercial line, 1845.

1846. Redfield suggested telegraph for storm warnings, (**15**).

1847. First storm warnings, Barbadoes, Carlisle Bay from barometer at Bridgetown (**68**, p. 297).

1846: Smithsonian Institution (**49h**, **54**, **56**) organized under executive direction of Joseph Henry (1799–1878) (**39**), pioneer physicist, whose name is now borne by the unit of magnetic induction. He had been in contact with the meteorological work in New York and at Philadelphia (**56**, pp. 212, 257–263). His program for the new Smithsonian Institution (**16**, 1847, pp. 6, 13) contemplated climatological observations and telegraphic reports for prediction of weather and storms, but was greatly hampered by meager funds. The Regents appropriated $1,000 for meteorological work at the end of 1848, and a corps of 150 observers was organized and began reporting 1849. Their number increased, and they were augmented as Henry procured the cooperation of the Surgeon General's hospital surgeons, Espy's observers in the Navy Department, the New York Academy observers, and of observers at grammar schools and light houses in Canada. Henry stimulated the beginning of state weather services in Massachusetts (1849), Maine, Illinois (1855), Texas (1858). The number of observers rose to 616 just before the Civil War, and reached 599 again in 1869. Suspension of payments by the First National Bank of Washington, in the panic of 1873, tied up the working funds of the Smithsonian and compelled Henry to ask the Signal Service to take over the Smithsonian observers, and this was done February 2, 1874 (**33**, 1874, pp. 88–89, 286–287).

Henry cooperated with the Commissioner of Patents, then in charge of government work in agriculture, prepared reports on the relations of meteorology to agriculture in exchange for the franking of observers' reports and the publication of observations at Government expense (**16**, 1855 pp. 26–28), (**30**). The title of the latter publication is misleading in suggesting that observations were made under the direction of the Patent Office. This cooperation suddenly ceased at the death of Patent Commissioner Mason, 1860, (**16**, 1850, p. 34), but on creation of the office of Commissioner of Agriculture, 1862, similar relations were established (**16**, 1863, p. 32). Results were published (**30**), (**35**). Lorin Blodget, climatologist, was employed to prepare the first (**16**, 1854, p. 25), but "set up such claims to a personal right of property in it" (**16**, 1855 p. 19) that it was taken away and given to Prof. J. H. Coffin, of La Fayette College (**52a**), who, followed by his son, performed many valuable services for the Smithsonian and for meteorology. The later volumes were prepared by C. A. Schott, of the Coast and Geodetic Survey.

1848: Jones & Co. (John D. Jones, agent, later vice president, and president to 1895, Atlantic Mutual Insurance Co., marine underwriters), Merchants Exchange, New York City, advertised "daily and hourly telegraphic meteorological reports" (**19**). Compare Francis Galton's Weather Map Company (**68**, pp. 306–308).

June 14, 1849: James Glaisher started first telegraphic weather reports for London Daily News (**68**, p. 302).

August 8, to October 11, 1851: Telegraphic weather maps lithographed and sold at a penny each, at the Crystal Palace Exhibition, London (**59**, p. 64), (**68**, p. 302).

November 14, 1854: Storm in Black Sea, during Crimean War, enabled Leverrier, discoverer of the planet Neptune, to procure Emperor Napoleon's consent for first national telegraphic weather service, beginning February 17, 1855, in France; extended over Europe, 1857; published daily bulletin, 1858; issued storm warnings, 1860 (preceded by Buys Ballot in Holland by a few months); published daily isobaric weather maps from 1863 (**59**), (**68**).

1857: Smithsonian telegraphic weather observations, arranged with presidents of telegraph companies in 1849 (**16**, 1850, p. 14), begun along lines New York to New Orleans and Washington to Cincinnati (**16**, 1857, pp. 26, 27). Weather reports published in "Evening Star" and exhibited to visitors to Smithsonian by hanging pieces of colored card on iron pins fixed in a map (**16**, 1858, p. 32); later these cards were cut into disks bearing arrows to show wind direction also, and were oriented by hanging from one of eight holes (**16**, 1869, p. 50). Compare this device with maps of Brandes, 1820, and Loomis, 1843.

Henry predicted weather for his own use in planning lectures and reported results to a scientific society (**28**), (**55**). These observations were crowded off the wires by war business in 1861, temporarily resumed 1862 (**16**, 1862), and contemplated again 1867 (**16**, 1867, p. 28.) Arrival of the French maps and beginning of weather services throughout Europe and in Turkey and India inspired Henry to urge in his annual reports (**16**, 1865, pp. 56–59) the establishment of an American national weather service. In spite of the presence of three senators and three representatives on the Board of Regents of the Smithsonian Institution, no action was taken to place Henry's recommendations before Congress (**56**).

The contributions of the Smithsonian to meteorology were listed by Henry (**16**, 1871, pp. 43, 57) as follows: Inaugurating the climatological observations which have been in operation upward of 20 years, introduction of improved instruments, publication of extensive series of meteorological tables, reducing and publishing material from all records since the first establishment of the country, showing the practicability of telegraphic weather signals, publishing Arctic observations, publishing special records, memoirs on meteorological subjects, diffusion of knowledge of meteorology through correspondence, urging upon Congress the establishment of a meteorological department.

1857: Capt. George Gordon Meade, Superintendent of the Survey of the North and Northwest Lakes, Corps of Topographical Engineers, United States Army, commander in chief of the Union army at the battle of Gettysburg, began meteorological observations at 25 stations on the Great Lakes. Results were published at Detroit and in reports of the Chief of Engineers (**29**), and manuscript

records forwarded to the Smithsonian. This service ceased 1872–1876 as the Signal Service extended over the same area.

September 1, 1869: Cleveland Abbe (1838–1916), director of the Cincinnati Astronomical Observatory, organized daily telegraphic reports from cities in the Middle West, and published a weather map with the support of the Cincinnati Chamber of Commerce for three months (**34**), afterward at Abbe's own expense for six months. Meantime, in February, 1870, Manager Armstrong of the Cincinnati office of the Western Union Telegraph Co., through whose hands Abbe's reports were received, started a similar publication, with which Abbe merged his efforts in May, 1870. This later publication, copies of which survive (67, p. 25) and in Lapham papers in Wisconsin Historical Society, exhibit the weather by discrete symbols and figures for weather, wind direction, and temperature, but no barometer readings, isobars, isotherms, nor weather predictions. Compare maps of Brandes, 1820, Loomis, 1843, and Paris Observatory, 1863. On July 20, 1869, Abbe and his friends organized a meteorological society, the Western Meteorological Association.

1869: Daniel Draper (1841–) organized the municipal meteorological observatory in Central Park, New York City, now operated by the United States Weather Bureau. Draper devised many automatic instruments for the observatory, which have also found use in industry.

1869, December 8: Increase A. Lapham (1811–1875), Quaker, philanthropist, naturalist, meteorological observer for Espy, Smithsonian Institution, Lake Survey, and Abbe, sent a memorial, "Disasters on the Lakes", (**32**), to Gen. Halbert E. Paine, Member of Congress from Lapham's home district at Milwaukee. This memorial enumerated the losses of sailors and ships on the Great Lakes in the storms of 1868 and 1869, cited Espy's laws of American storms, and Leverrier's successes in giving warning of European storms. This scientific, humanitarian, and economic appeal, the solidarity of Congress, then filled with Union officers accustomed to work together, contributed to Paine's success in procuring the passage of the Act of Congress, February 9, 1870 (16 Stat. 369), directing the Secretary of War to take meteorological observations and give warning of the approach of storms. On February 28, 1870, the Secretary of War assigned this duty to the Chief Signal Officer (**33**, 1870, p. 16), an office that originated June 27, 1860, when Asst. Surg. Albert J. Myer was appointed Major and Signal Officer to develop a system of military communication that he had invented (51). Although he had not held that office continuously, Myer was Chief Signal Officer in 1870 when the meteorological work was authorized by Congress, and Paine states (Lapham Papers) that Myer secured its assignment to his administration, where it was designated the "Division of telegrams and reports for the benefit of commerce." Sketches of the Signal Service (41), (46), (52*a*) and of the Weather Bureau (66) are available, so that only a few points will be given here.

The initial appropriations for meteorological work by the Signal Service were: Year ending June 30, 1870, $15,000; 1871, $50,000; 1872, $102,451; 1873, $250,000. These figures do not include pay or allowances of officers and enlisted men. The total appropriation exceeded a million dollars in 1884 and 1885, and was mostly expended on meteorological work.

Observations commenced November 1, 1870. The first forecaster was Increase A. Lapham, "assistant to the Chief Signal Officer," stationed at Chicago, with supervision over the signal service on the Lakes until the close of navigation, 1870, who issued the first storm warning at noon, November 8, 1870. Lapham drew isobaric maps such as forecasters use to day (**33**, **1871**, **pp**. 7, 167–172, and 15 charts).

In order to enlist state aid in distributing agricultural warnings and to collect agricultural and climatological observations, State Weather Services (**49 d, e, 50**) were organized from 1883 onward by Lieut. H. H. C. Dunwoody, who had suggested them in 1881 (41). In October 1895 control of these services passed from the states to the United States Weather Bureau, and with the "voluntary observers" of the Smithsonian net were then merged in the Climate and Crop (now Climatological) Service of the Weather Bureau.

Beginning about 1884, agitation for conversion of the meteorological service into a civilian bureau brought a series of bills before Congress. The Act of October 1, 1890 (26 Stat. 653), introduced by Senator William B. Bate, of Tennessee, effected the transfer to the Department of Agriculture. The magnitude of the change is best seen by comparing the expenditures of the Signal Corps before and after the change on June 30, 1891: 1891, $753,284.70; 1892, $31,697.62. The chiefs of the meteorological service, with dates of appointment have been:

July 28, 1866: Brig. Gen. Albert J. Myer (1828–1880).
December 15, 1880: Brig. Gen. William B. Hazen (1830–1887).
March 3, 1887: Brig. Gen. Adolphus W. Greely (1844–).
July 1, 1891: Mark W. Harrington (1848–1926).
July 4, 1895: Willis L. Moore (1856–1927).
August 4, 1913: Charles F. Marvin (1858–).

Published results are considerably too numerous to mention, but summaries of summaries will be found in Bulletins Q and W of the Weather Bureau and in the Atlas of American Agriculture. The publications of the Signal Service and of the Weather Bureau have been listed (48), (63).

1884–1896: The New England Meteorological Society, W. M. Davis, secretary, was organized to operate the state weather service as a unit for New England (42), (**53**). It also functioned as a scientific society, holding meetings, and by cooperative investigation of sea breeze, thunderstorms, etc. Meetings and papers were reported in the American Meteorological Journal, results in Publications of Harvard College Observatory.

1884: Abbott Lawrence Rotch (1861–1921) founded Blue Hill Meteorological Observatory, primarily for research on clouds, instruments, and upper air observations with kites and balloons, the latter extended, 1905, to the trade-wind region of the Atlantic in cooperation with Teisserenc de Bort. Rotch was active in support of the New England Meteorological Society and the American Meteorological Journal. Since 1912 the observatory, bequeathed to Harvard University has been directed by Alexander McAdie, former official of the United States Weather Bureau. Among Blue Hill meteorologists are H. H. Clayton, S. P. Fergusson, C. F. Brooks, A. H. Palmer (62, 73). Results published in Annals of Harvard College Observatory and Publications of Blue Hill Observatory.

1917: The World War brought into existence the Meteorological Section, Signal Corps, United States Army (64), and the Aerographic Section, United States Navy (65).

1919: The American Meteorological Society, C. F. Brooks, secretary, open to meteorologists throughout North and South America, was organized (**72**).

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1861	1118	1	95
1862-63	1184	-------	201, 491
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SOIL TEMPERATURES IN THE UNITED STATES [1]

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By writing to all the agricultural experiment stations and examining the available literature on the subject, soil

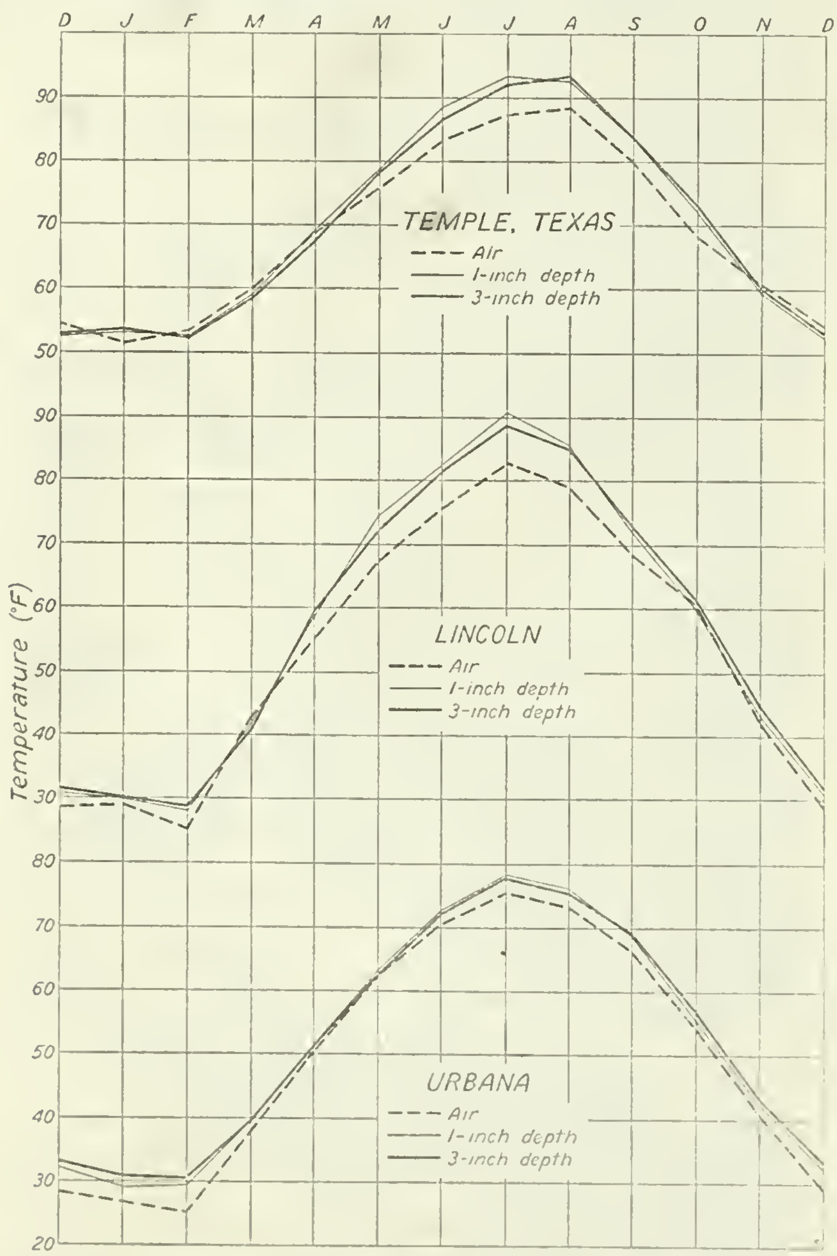

FIGURE 1.—Air and soil temperatures at Temple, Tex., Lincoln, Nebr., and Urbana, Ill.

temperatures for 32 stations in the United States have been obtained.[2] Only the very cordial cooperation of the agricultural experiment stations, the library of the United States Weather Bureau, and certain individuals has made possible the collection of the data. The stations, though few in number, are fairly representative of the country as a whole.

Many variations in the conditions under which the soil temperatures were taken occur. In general, the experiment stations obtained soil temperatures not because of interest primarily in the temperatures themselves, but to determine the extent to which the temperatures were favorable or unfavorable for an important local crop or for bacteria harmful or helpful to that crop. Thus the thermometers were often placed at the depth at which the seed would be planted, so the depths for the different stations vary considerably. Also, because the interest was chiefly in connection with crops, records were often taken only during the growing season instead of throughout the year. Soils such as clay, loam, sand, peat, etc., are indicated; soil covers are various—bare, cultivated, sod, orchard, tobacco, cotton, mulches, etc.; exposures noted at different stations indicate variations between hillsides and bottom lands, dry soil and wet soil, shade and sun, etc. The accompanying table of soil temperatures indicates these variations where possible; it will be noted that some stations make no specification whatever as to the soil, soil cover, or exposure at the place where the soil thermometers were placed. In cases where temperatures of several kinds of soil or soil cover or exposure were recorded at one station, all of the data are included in the table for purposes of comparison at the station itself.

The material was sent to the authors in many different forms—some of it had already been published; some was in the form of graphs from which the desired temperatures could be read; in many instances the original thermograph records were sent and readings and tabulations were made from them; often a letter from an official of the station indicated all the soil temperatures that the station had available. Where possible, the temperatures in the tables were obtained by averaging the mean daily maximum and mean daily minimum temperatures for each month.

It is very apparent that the soil temperatures obtained for the 32 stations are by no means uniform—variations occur in the years, months, or days of record, the method

[1] Based on a paper presented before the Association of American Geographers at Worcester, Mass., December 29, 1930, by Edith M. Fitton.

of taking the record and of compiling tables from it, the kind of soil, depth, soil cover, and exposure. Hence the records at different stations are not strictly comparable with one another; however, the data are valuable for the individual stations, especially when temperatures for different depths, soils, and exposures are recorded at a single station. The scantiness of the material now available emphasizes the need for many additional observations of soil temperatures, which should be made under conditions as uniform as possible.

A study of the tabulated records now at hand and the graphs which illustrate them suggests a number of conclusions.

(*a*) Air and soil temperatures near the surface vary in a fairly parallel manner.

Since the temperature of the air is chiefly dependent on radiation and conduction from and to the ground, it follows that the diurnal and annual courses of the air temperatures and the ground temperatures should be quite similar. A number of stations provided air temperatures as well as soil temperatures. (See fig. 1 and the accompanying tables.)

(*b*) The soil temperatures at slight depths are generally higher than the air temperatures throughout the year. (Fig. 1.)

By day and especially in summer the ground is warmed to a much higher temperature than the air above it, so much so that, though it is cooled to a lower temperature at night, the mean temperature of the ground remains higher than that of the air. At Urbana, Ill., "the average monthly temperature of the soil to a depth of 1 to 3 inches is always higher than that of the air above it" (**14**, p. 42), but at Lincoln Nebr., (**21**) and at Temple, Tex., this statement does not hold true in the spring and fall. In the spring the reason is perhaps that it takes longer for the soil, continually cooled by conduction from below to warm up; in the fall, with shorter days and a longer period of nocturnal radiation, the soil cools more rapidly, though, as the winter months show, not to as great a degree as the air. Because of intense surface heating, the summer months show the widest variation between the air and soil temperatures, the soil at the 1-inch depth being considerably warmer than at 3 inches, with the interesting exception of August at Temple, Tex. The explanation for the exception probably lies in the fact that the deeper soil has become thoroughly warmed during the long summer of this southern station, and, since it retains its warmth at night better than the surface soil, its temperature shows a higher monthly average.

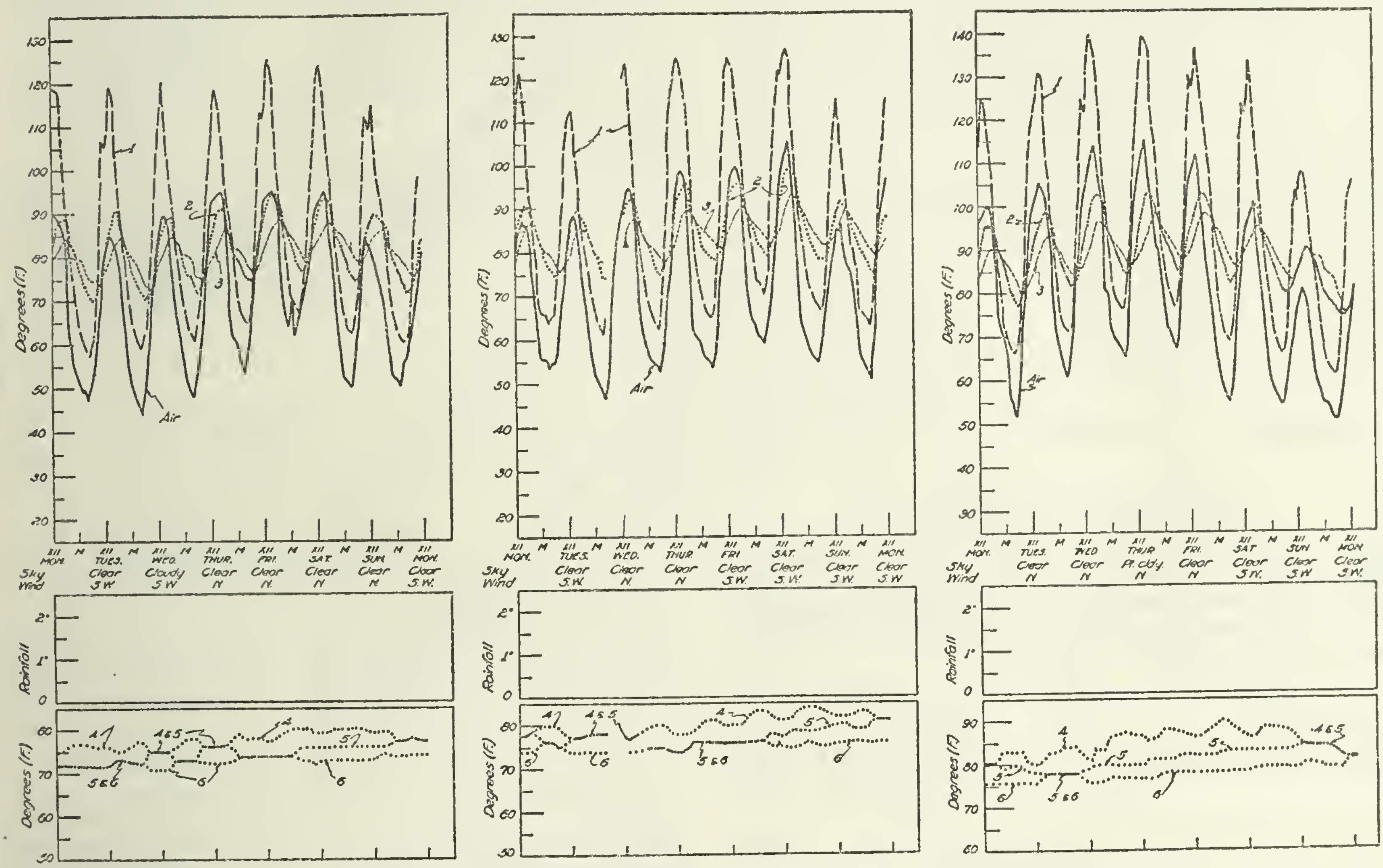

FIGURE 2.—Weekly courses of soil temperatures at different depths at Davis, Calif.

(*c*) The diurnal range in soil temperatures extends to a depth of about 3 feet (**60**, p. 79).

A study of the original thermograms which were sent by a number of stations showed this to be a fact, as does also Figure 2, from a soil paper by Alfred Smith published in Hilgardia (**32, a**, p. 91). The 36-inch-depth line is seen to have the least fluctuation during the weeks shown.

(*d*) The annual range in soil temperature is quite apparent at a depth of 10 feet, the greatest depth for which a record is obtainable in the United States.

Bozeman, Mont. (fig. 3) furnished soil temperatures to a depth of 10 feet. Here the annual range is still reasonably apparent and it probably extends to a depth of 30 or 40 feet (**60**, p. 80). Where the temperature line for the 10-foot depth is superimposed on the 1-foot temperature line, the greatly decreased annual range with

depth is at once apparent. The increase in uniformity of temperature with increase in depth, progressively indicated from top to bottom of Figure 3, is due to the fact that in the summer time with increasing depth the soil becomes colder; in the wintertime, with increasing depth, the soil becomes warmer.

(*e*) The lag of maximum and minimum soil temperatures increases with depth.

According to Alfred Smith's experiments at Davis, Calif., the lag "varies from less than 1 hour at the ½-inch

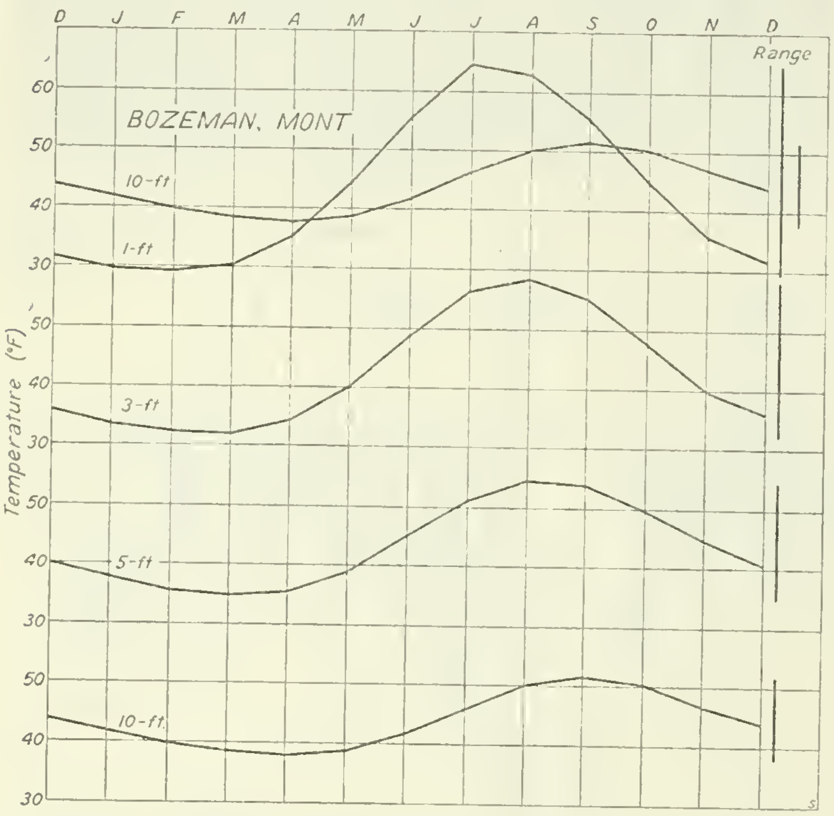

FIGURE 3.—Soil temperatures at Bozeman, Mont.

depth to approximately 80 hours at the 36-inch depth (**32b**, p. 111). Figure 3 shows that at the 10-foot depth the lag in annual maximum and minimum is as much as four or five months, September and April being the months of the extreme temperatures.

(*f*) A cover crop lessens the diurnal and annual temperature ranges.

The tables show only three stations that supplied soil temperatures specifying several different soil covers;

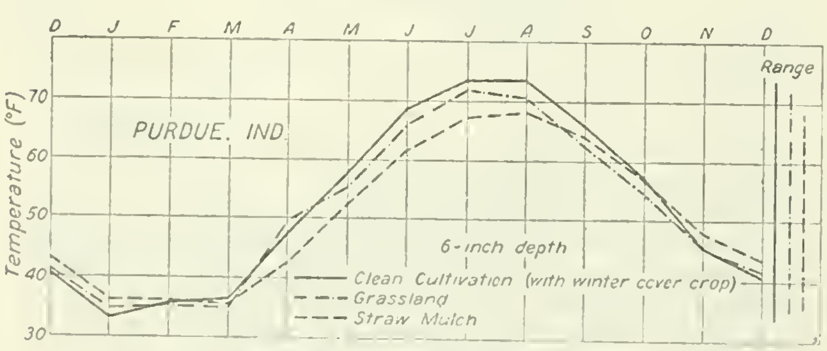

FIGURE 4.—Soil temperatures under different cover crops at Purdue, Ind.

the data for Purdue, Ind., are shown in Figure 4. The mean annual range under straw mulch is least; under clean clutivation it is greatest. The spring and summer months show the greatest differences in temperature between the soil under clean cultivation and that under straw mulch, because the bare ground warms up so much more rapidly as well as to a greater degree than the ground under straw.

(*g*) In the winter time, northerly stations where the snow cover is more or less permanent show higher mean monthly soil temperatures than stations somewhat farther south or west but lacking a good snow cover.

By means of Figure 5, the winter air and soil temperatures at East Lansing and Lincoln (21) may be compared. While the air temperatures at East Lansing average 5° F. or more below those at Lincoln, the soil temperatures are several degrees higher than those at Lincoln. The explanation seems to lie in the fact that a snow cover of fairly permanent duration maintains the soil temperatures at about 32° regardless of the air temperature, whereas

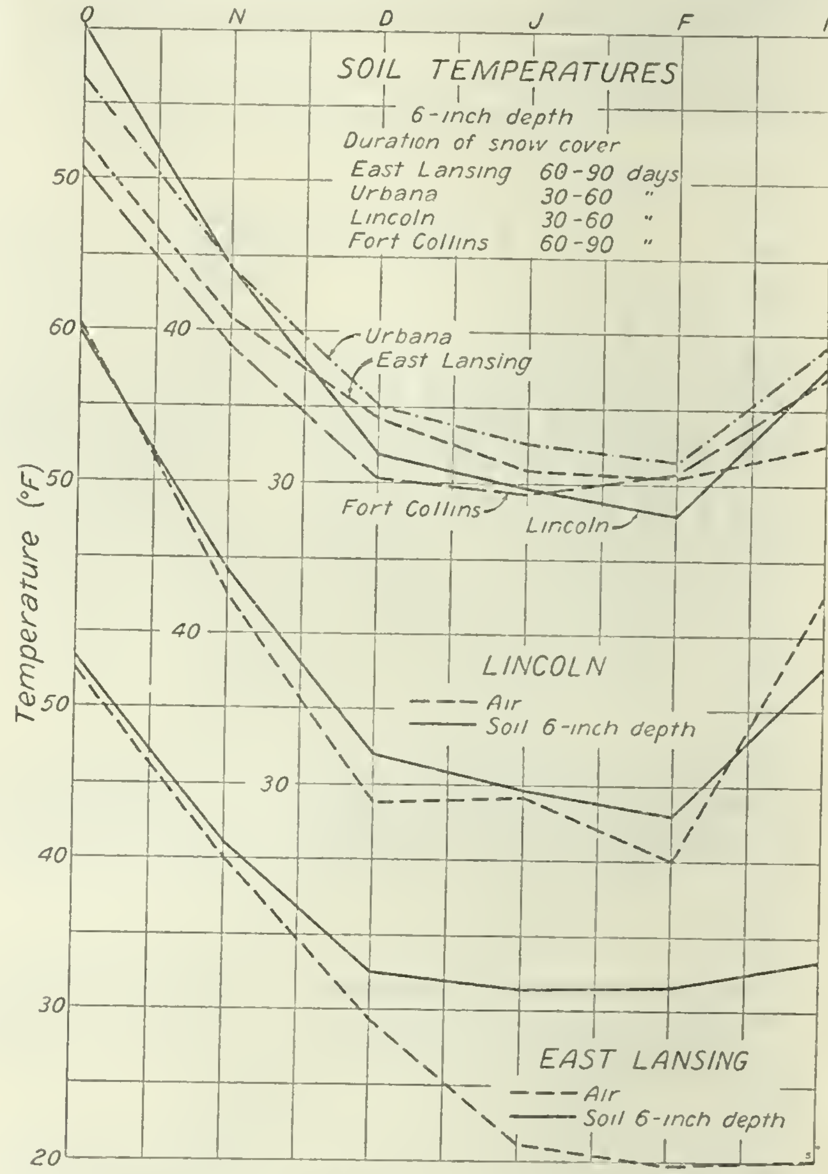

FIGURE 5.—Winter-time soil temperatures at East Lansing, Mich., Urbana, Ill., Lincoln, Nebr., and Fort Collins, Colo.; air and soil temperatures at East Lansing and Lincoln

lack of snow cover allows the soil temperature to average lower than the freezing point under winter conditions that in general favor surface temperatures below freezing. The winter time soil temperatures at Fort Collins are of interest. (Fig. 5.) Early in the winter this station has low soil temperatures, probably due to early cooling because of altitude and lack of early snow cover. Later in the winter, however, the deeper snow cover prevents the soil temperatures from falling any lower and even insulates the soil sufficiently to allow warmth from below to cause a slight rise in soil temperature.

A uniformity of temperature throughout the winter months which is probably maintained by the snow cover is apparent in most of the illustrations.

(*h*) The presence of moisture in the soil tends to give a low and uniform temperature.

Auburn, Ala., Columbia, Mo., and Corvallis, Oreg., have furnished soil temperatures specifying whether the soil is wet or dry. At Auburn the wet bottom-land soil seems to be warmer than the dry hilltop soil, but this may be merely the result of the method of obtaining the means by averaging the maximum and minimum temperatures, for the minimum temperatures on the wet ground are several degrees higher than on the dry sandy ground. At Columbia the "seepy spot" on the slope is generally cooler by about 1° than the other two exposures, both at the 12-inch and 36-inch depths. In 3 instances out of a possible 24 comparisons the seepy spot was found to be warmer than the other exposures.

At Corvallis the difference is between irrigated and unirrigated soils. The conclusion is that "the presence of irrigation water and the resulting evaporation tends to give a low uniform temperature, but the difference due to irrigation would decrease with depth" (**31**, p. 30). At East

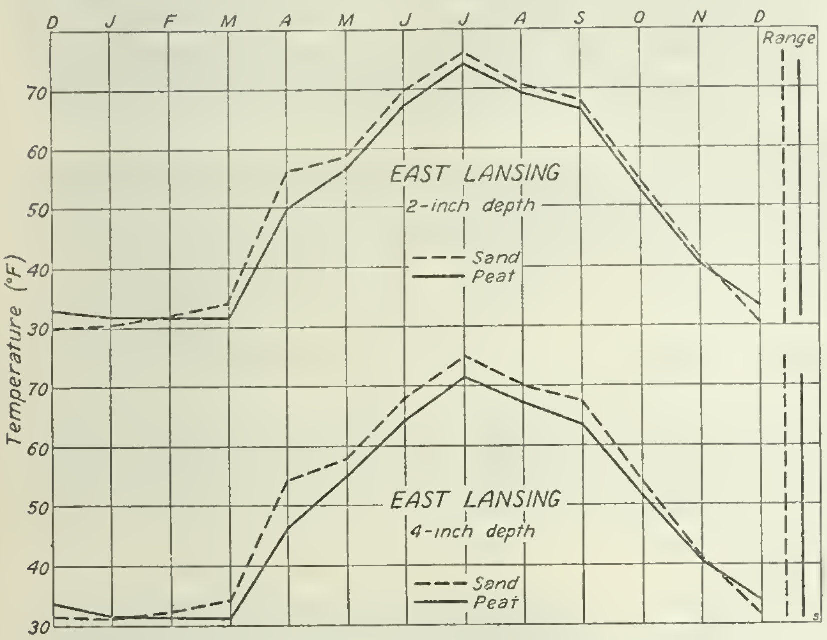

FIGURE 6.—Temperatures of sand and peat soils at East Lansing, Mich.

Lansing, Mich. (fig. 6), a comparison between the dry sand and the moist peat soils shows that peat tends to maintain a more uniform temperature than sand, being warmer in winter and cooler in summer.

(*i*) Loam, clay, and peat soils never become as warm in summer as the drier gravel and sand soils.

Figure 6 and the data in the table for East Lansing, Mich., show that at all depth highest summer temperatures are found in the sandy and gravel soils, lowest temperatures in the peat and clay soils. In the winter time all of the soils tend to be at a temperature of about 32° F. when under a snow cover.

(*j*) Soil temperature and its annual range decreases with altitude.

The upper portion of Figure 7 shows the decrease of temperature with increasing altitude for both north and south slopes. The lower portion of the figure shows the lessening range with increase in altitude.

(*k*) South exposures at any altitude have higher temperatures and a greater range than north exposures.

The lower portion of Figure 7 shows this graphically. It is of interest to note how much less rapidly the maximum temperatures on the south slope decrease with altitude than the maximum temperatures on the north slope. The mean temperatures for the south exposures averages 12° F. or more above those for the north exposures at the same levels, and even at 9,000 feet the mean for the south exposure is still almost 5° higher than the mean for the north exposure at only 7,000 feet.

Daily and monthly ranges, shown in Tables 2 and 3 for certain stations, provide further quantitative comparisons of soil temperature characteristics at different depths at the several seasons and in various climates. Daily ranges are greatest nearest the surface. The 1922–1925 series at Fargo, N. Dak. (**18**), described as an unusually warm period, had a daily range at 1-inch depth in excess of the range of air temperature a few feet above the ground. The other Fargo series (**19**), however, at ½-inch depth showed a range only one-fourth to one-third as great as that at 1

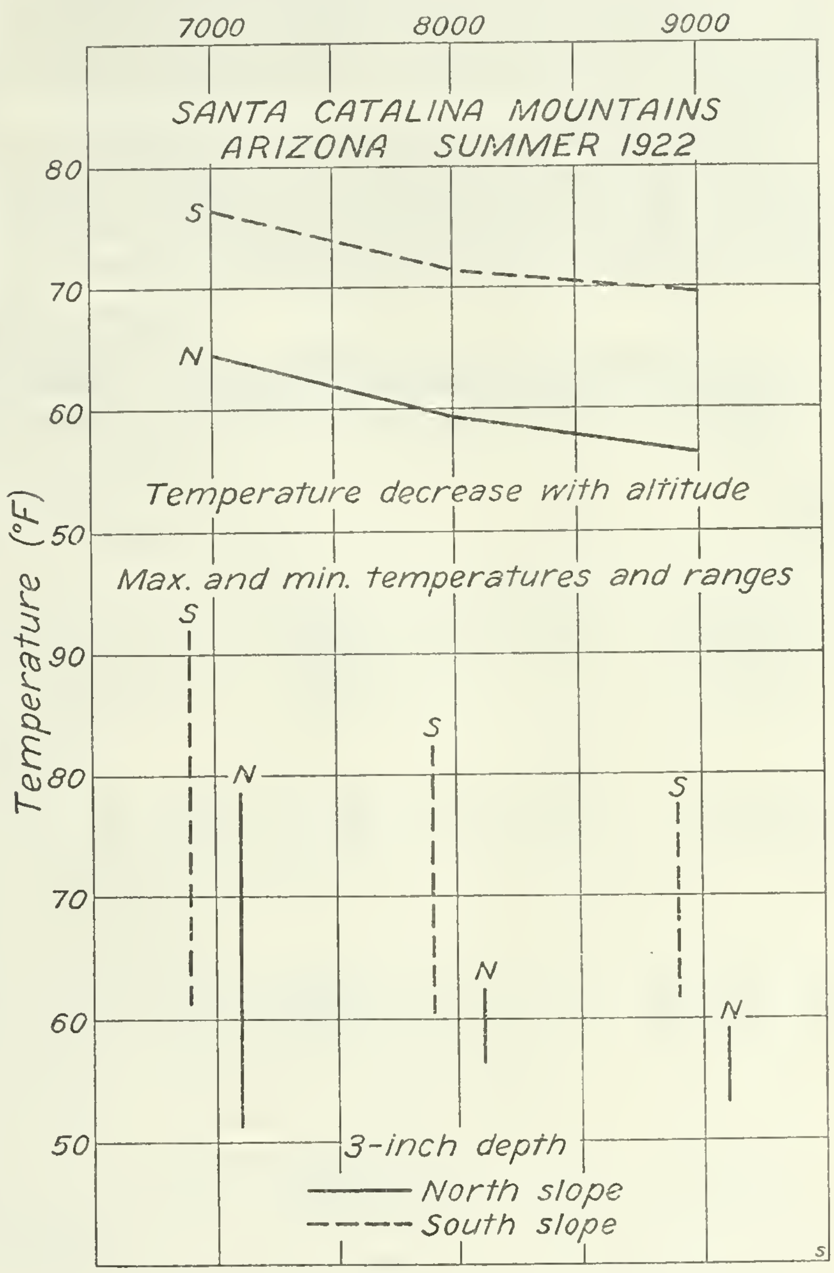

FIGURE 7.—Mean, maximum, and minimum temperatures at different altitudes on the north and south sides of the Santa Catalina Mountains, Ariz.

inch in the first series. In general (Table 2), the range of soil temperature at the 3-inch depth was about three-fourths the range of air temperature in the warmer half year and less than two-thirds of the reduced air temperature range in the colder half year.

From this general surface layer downward the daily range decreases geometrically. In the most complete New Haven series (4) the daily range decreases by about half for each 3-inch increase in depth, becoming at 12 inches only one-fifth to one-tenth that at 3 inches. In the other New Haven series (5), the range at 6 inches is about the same as in the first, but that at 12 inches is still nearly as large, and the range at 18 inches is much like

that at half the depth in the first series. As these observations were made in borings, a more rapid exchange of heat than usually occurs in the ground may have taken place in these holes. In the New York Botanical Gardens daily ranges at a depth of 1 foot in clay soil mixed with loam were about the same as at the same depth in the first New Haven series, namely 1° to 2(+)° F.

Any covering on the soil reduces the daily range markedly. In the Purdue experiment (**13**) ranges at 6 inches under straw were only 2.5° to 5° F., while those under clean cultivation were 8° to 12° F. in the warmer half year. Ranges under grassland were nearly as large as those under clean cultivation, however. Ranges under straw, cover crop, or grass were all about the same in winter, generally 3° to 5° except in January, when reduced to 1.4° (cover crop) to 2.1° (grassland) probably by the snow cover.

The effect probably of snow cover is also seen in the ranges at Wooster and Columbus, Ohio (**11**), where the range at 6 inches is smaller in proportion to that at 1 inch in winter than in summer. In the colder half year the range at 6 inches is only one-fourth of the 5° range at 1 inch, while in the warmer half year the range at 6 inches is one-third of the 20+° range at 1 inch. In general there are much smaller daily ranges at slight depths in winter than in summer, though the range of air temperature is not changed so much. The air temperature range decreases by a third, while that of the soil decreases by a half to three-quarters or more. At a depth of 18 inches, for which depth we have ranges through the year only at Lexington, Ky. (**12**), the diurnal range becomes about the same small value, 1° F., in all months.

The drier climates, so far as these samples go, have the larger daily ranges of soil temperature. Also the drier months in the warm season have the larger ranges. The ranges at Fargo, N. Dak. (**18** and **19**), increased markedly toward late summer as the normal convectional rainfall decreased.

Monthly ranges (Table 3) are considerable to depths of 12 inches in the north and 24 inches in the south. They decrease fairly rapidly with increase of depth, but proportionally not nearly so fast as the daily ranges. At Temple, Tex., the temperature even at a depth of 4 feet has a mean annual monthly range of more than 5° F.

TABLE 1.—*Soil temperatures* (°*F.*)

Figures for every day of each month or for every month over a period of years are not always available. Where the record covers only one year, the actual number of days of record is given as an exponent of the temperature figure in those months in which there is not a record for every day; when data are available over a period of several years, those averages in which several days of one or more months are missing or in which a whole month or more is missing are indicated thus (*)

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

AMHERST, MASS.—TOBACCO FIELD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(1)	1927-28	5 inches						*65.5	*71.8	69.4	*67.6				
(2)	1929	2 feet	[1] 36.0	[1] 34.0		[1] 43.0	[1] 57.0		[3] 69.0						
(2)	1929	3 feet							[3] 60.0						
(2)	1929	4 feet	[1] 37.0	[1] 38.0		[1] 41.0	[1] 50.0								
(2)	1929	8 feet	[1] 45.0	[1] 42.0		[1] 41.0	[1] 46.0		[3] 55.0						

STORRS, CONN.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(3)	1922	Air							[18] 68.8	[27] 66.9	[12] 65.0				
		6 inches							[18] 73.0	[30] 70.6	[12] 66.2				

NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(4)	1926	Air					[21] 65.2	70.0	77.0	75.8	67.4	56.0	[24] 47.3		
		3 inches					[8] 60.7	[29] 68.4	81.2	[30] 74.9	[28] 67.0	54.4	[18] 46.1		
		6 inches					[8] 66.3	[29] 65.7	74.8	[30] 73.1	[27] 65.9	54.5	[17] 47.0		
		9 inches					[2] 58.6	65.0	72.4	[30] 72.4	[25] 66.1	54.8	[19] 46.8		
		12 inches					[9] 56.1	[29] 63.4	71.2	[30] 71.2	[28] 65.2	[30] 55.2	[18] 48.2		

NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(5)	1924	Air				45.0	53.2								
		6 inches				44.2	54.2								
		12 inches				43.5	52.6								
		18 inches				43.2	51.6								

NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(6)	1902	Air						[22] 63.9	70.2	68.2	61.9	[25] 53.4	[24] 46.6	[14] 31.3	
		12 inches						[21] 48.2	51.6	[30] 48.2	43.5	35.8	29.5	[21] 29.7	

BLACKSBURG, VA.—HAGERSTOWN SILT LOAM IN AN ORCHARD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(7)	1915	Air							70.2	68.2					
		3 inches							76.4	74.3	Sod.				
		24 inches							70.0	71.2	Do.				
		3 inches							75.8	75.0	Partially cultivated.				
		24 inches							69.3	69.9	Do.				
		3 inches							76.1	76.0	Intensely cultivated.				
		24 inches							69.4	70.5	Do.				

ATHENS, GA.—LAND BEDDED UP FOR COTTON

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(8)	192[illegible]	Air					68.3	Average from Apr. 22 to May 20.							
		1.5 inches					68.4	Do.							

TABLE 1.—*Soil temperatures (°F.)*—Continued

AUBURN, ALA.—SANDY SOIL ON A HILL, FREQUENTLY CULTIVATED DURING CROPS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(9)	1889	Air	46.9	46.3	54.7	62.5	70.1	76.1	80.7	77.6	74.8	62.3	53.1	57.8	63.6
		3 inches	48.5	50.5	55.2	65.5	72.2	74.0	86.5	82.2	75.5	64.8	52.2	52.0	64.9
		6 inches	48.2	55.5	53.8	64.8	72.0	73.5	85.8	81.5	75.0	65.2	52.8	51.2	64.9
		24 inches	49.5	50.5	53.8	62.5	70.5	74.2	81.5	80.0	80.8	68.2	58.8	55.0	65.4
		48 inches	52.5	50.5	53.5	59.8	67.2	72.2	77.0	78.0	79.8	70.8	63.5	58.5	65.3
		96 inches	58.0	55.5	55.2	57.2	61.2	67.2	71.0	73.2	75.0	72.5	77.0	63.5	65.5

AUBURN, ALA.—BOTTOM LAND ON THE BANK OF A SMALL STREAM

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(9)	1889	3 inches	48.0	51.0	55.2	64.0	73.8	75.0	87.5	83.2	76.2	64.8	52.8	51.8	65.3
		6 inches	48.8	51.5	55.2	65.8	73.5	74.5	86.8	83.0	76.0	65.5	53.0	50.5	65.3
		24 inches	51.2	51.8	54.5	63.0	70.5	74.8	81.2	80.2	77.5	68.8	59.2	55.0	65.6
		48 inches	53.5	52.2	54.2	60.5	67.2	72.2	77.0	78.0	77.0	71.2	63.5	59.0	65.5

EAST LANSING, MICH.—LOAM

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.3	31.5	33.3	55.2	57.0	67.9	73.4	68.5	67.2	53.4	41.0	32.5	51.0
		4 inches	32.0	32.1	33.9	53.0	56.4	66.4	72.8	68.1	65.9	52.8	41.4	33.6	50.7
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	32.6	45.4	57.0	68.9	74.0	70.6	64.8	52.6	40.7	34.2	50.2
(10)	December, 1911, to November, 1914	12 inches	32.7	31.7	32.5	42.0	55.5	67.6	73.0	70.9	65.1	54.1	42.4	36.7	50.4
		18 inches	34.5	33.1	33.1	40.8	53.1	64.3	70.2	69.3	64.5	55.1	44.0	38.6	50.0
(10)	December, 1911, to November, 1915	Air	21.2	19.8	30.1	48.1	57.1	66.3	71.4	68.5	63.4	52.6	40.1	29.4	47.3

EAST LANSING, MICH.—GRAVEL

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.8	32.2	34.3	56.2	58.5	69.8	75.7	70.5	67.7	53.7	41.4	32.3	52.0
		4 inches	32.3	32.7	34.4	54.8	57.8	67.9	74.2	69.4	66.7	53.6	41.7	33.0	51.5
(10)	December, 1911, to November, 1915	6 inches	31.2	31.0	33.6	47.6	58.4	70.4	75.0	71.5	65.4	53.2	40.9	34.2	51.0
(10)	December, 1911, to November, 1914	12 inches	32.1	31.4	33.5	44.0	56.6	68.7	73.6	71.0	64.7	53.6	41.6	35.8	50.6
		18 inches	33.7	32.8	33.7	42.8	55.0	66.8	72.2	70.4	64.9	54.6	43.1	37.6	50.6

EAST LANSING, MICH.—SAND

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	30.6	32.2	34.3	56.2	58.7	70.0	76.2	70.8	68.2	54.1	41.1	30.2	51.9
		4 inches	31.3	32.7	34.5	54.4	58.1	68.6	75.0	70.0	67.4	54.0	41.5	31.8	51.6
(10)	December, 1911, to November, 1915	6 inches	30.5	30.5	33.6	47.7	58.5	69.9	74.5	71.4	65.3	53.0	40.5	33.8	50.8
(10)	December, 1911, to November, 1914	12 inches	32.2	31.4	33.4	42.9	56.3	67.8	72.8	70.7	64.5	53.6	41.9	36.0	50.3
		18 inches	34.3	33.0	33.9	42.5	54.4	65.5	71.1	69.9	64.8	55.0	43.8	38.3	50.5

EAST LANSING, MICH.—CLAY

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.9	32.1	33.9	54.4	57.4	67.8	74.4	69.4	66.7	52.9	41.1	32.3	51.2
		4 inches	32.0	32.3	33.7	52.0	55.3	65.5	71.6	68.2	65.5	52.3	41.2	33.0	50.2
(10)	December, 1911, to November, 1915	6 inches	31.3	30.9	33.2	45.7	57.2	68.8	73.8	70.5	64.8	52.8	41.2	34.4	50.4
(10)	December, 1911, to November, 1914	12 inches	32.7	31.7	32.9	42.3	55.5	67.0	72.2	70.2	64.6	53.5	42.2	36.6	50.1
		18 inches	34.2	32.8	33.3	41.5	54.2	65.3	70.9	69.8	64.9	55.1	43.9	38.2	60.3

EAST LANSING, MICH.—PEAT

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	32.0	31.9	31.9	-49.9	56.7	67.5	74.2	69.4	66.9	52.9	40.5	33.3	50.6
		4 inches	31.9	31.7	31.6	46.6	55.0	64.6	71.5	67.5	64.7	51.5	40.7	34.0	49.3
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	31.4	41.1	56.8	68.5	73.9	71.0	65.1	52.9	40.9	34.7	49.8
(10)	December, 1911, to November, 1914	12 inches	32.6	31.6	31.9	38.6	54.7	66.9	72.1	71.3	65.6	54.8	42.8	36.6	50.0
		18 inches	35.2	33.7	33.4	37.8	53.2	64.5	70.8	70.3	65.6	56.4	45.2	39.2	50.4

WOOSTER, OHIO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(11)	1924 to April, 1925	1 inch	*30.3	32.5	*35.2	*47.3	50.8	62.6	63.0	[18] 62.3	--------	50.4	37.4	32.0	--------
		6 inches	*35.0	37.2	*41.0	*44.8	51.8	65.3	68.8	[24] 69.6	--------	50.6	40.6	34.4	--------

COLUMBUS, OHIO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(11)	1923	1 inch	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	[4] 43.0	43.4	--------
		6 inches	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	[4] 48.4	[30] 49.2	--------

LEXINGTON, KY.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(12)	1922–1927	3 inches	*32.7	*35.5	*42.1	*56.0	*62.8	*74.6	*77.1	*76.7	*73.1	*58.3	*45.6	39.2	56.1
(12)	June, 1928 to June, 1929	4 inches	[24] 20.4	17.3	35.4	[29] 49.8	[24] 55.6	*69.4	75.4	[30] 74.6	63.3	55.8	37.6	[30] 24.4	48.2
(12)	1922–1929	18 inches	*36.3	*35.9	*41.5	*52.0	*57.5	*67.8	*70.6	*73.4	*70.2	*59.8	*49.1	41.1	54.6
(12)	1922–1923	36 inches	*41.8	*40.5	*44.0	*50.3	*56.2	*65.8	*70.5	*73.4	*68.8	*62.0	*53.9	47.5	56.2

PURDUE, IND.—CLEAN CULTIVATION WITH WINTER COVER CROP

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(13)	May, 1913, to May, 1915	6 inches	33.3	35.9	36.4	47.8	57.6	68.8	73.5	73.9	66.0	57.4	45.6	40.6	53.0

PURDUE, IND.—STRAW MULCH

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(13)	May, 1913, to May, 1915	6 inches	36.3	36.2	35.4	42.6	52.4	61.6	67.3	68.2	64.1	57.3	48.0	43.3	51.1

TABLE 1.—*Soil temperatures* (°F.)—Continued

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	PURDUE, IND.—GRASS LAND														
(13)	May, 1913, to May, 1915	6 inches	35.0	35.6	35.1	49.7	55.5	66.0	71.9	70.6	62.7	54.9	45.6	41.4	52.0
	URBANA, ILL.														
(14)	1897–1916*	Air	26.9	25.4	38.3	50.2	62.4	70.6	75.5	73.3	66.1	54.4	40.9	28.6	51.0
		1 inch	29.2	29.5	39.8	51.0	63.0	72.6	78.2	76.2	69.0	55.5	42.2	32.1	53.2
		3 inches	31.0	30.6	39.5	50.6	62.2	72.2	77.8	75.8	69.0	56.8	43.0	33.4	53.5
		6 inches	32.6	31.5	39.3	49.2	60.5	70.5	75.8	74.8	68.8	57.0	44.0	35.0	53.2
		9 inches	33.2	33.0	39.2	48.7	59.8	69.4	74.7	74.0	68.6	57.4	45.2	36.0	53.3
		12 inches	34.0	33.2	38.6	48.4	58.8	68.0	73.8	73.2	68.2	58.0	46.2	37.4	53.2
		24 inches	37.6	37.1	38.6	47.1	55.4	62.6	68.5	69.7	66.7	59.5	50.6	42.7	53.0
		36 inches	41.0	38.8	40.1	46.0	53.6	60.3	66.0	67.8	66.1	60.7	53.0	45.8	53.3
	CHICAGO, ILL.—ST. IGNATIUS' COLLEGE														
(15)	1897–1900	Air	27.7	25.2	36.4	45.8	60.3	62.9	73.6	70.5	65.5	56.7	41.2	29.8	49.7
		4 feet	43.9	41.0	42.2	46.4	53.4	60.8	67.1	68.5	67.4	60.5	55.2	47.0	54.4
	COLUMBIA, MO.														
(16)	1928	Air			[25] 39.3	[29] 44.3	[30] 57.9	62.5	[30] 71.4	[30] 69.6					
		12 inches			[22] 45.0	[27] 49.5	[28] 57.9	[26] 64.0	[26] 71.4	[26] 72.3	[1] Near top of gentle slope.				
		36 inches			44.8	50.5	61.9	66.9	75.7	74.2					
		12 inches			44.2	49.3	57.4	63.7	70.9	71.6	[2] About 200 feet from [1], a seepy spot on slope.				
		36 inches			45.0	50.2	62.1	66.9	75.4	74.8					
		12 inches			44.4	49.5	59.7	65.3	73.4	73.8	[3] About 400 feet from [1], at lower part of slopo.				
		36 inches			45.1	50.7	63.5	68.0	77.2	76.6					
	FAYETTEVILLE, ARK.														
(17)	May, 1928, to May, 1929	Air	35.8	[20] 33.3	50.9	58.3	*64.6	68.7	77.2	[30] 77.9	68.2	64.6	46.9	[30] 40.1	57.2
		5 inches	40.5	[20] 38.3	51.3	60.6	*65.5	70.7	83.3	[30] 84.9	73.9	69.6	[26] 55.9	[30] 43.9	61.5
	FARGO, N. DAK.—SCIENCE GARDEN														
(18)	1922–1925*	1 inch					62.3	69.7	77.0	76.4	61.2	49.8			
	FARGO, N. DAK.														
(19)	1929–30	Air			*42.9	*54.8	64.4	72.6	70.2						
		½ inch			*44.8	*59.8	68.9	73.7	72.2						
	BROOKINGS, S. DAK.														
(20)	1888	Air (maximum)						84.0	78.2						
		2 inches						81.6	75.4						
		12 inches						69.5	69.7						
	LINCOLN, NEBR.—BARE SOIL														
(21)	1900–1904	Air	29.2	25.1	42.8	56.5	67.8	75.6	82.7	79.1	68.4	60.7	42.5	28.8	54.9
		1 inch	30.0	28.2	42.4	58.6	74.5	82.3	90.8	85.6	72.0	60.0	43.5	31.0	58.2
		3 inches	30.0	28.7	41.1	59.3	72.1	81.2	88.6	85.3	72.9	61.4	44.3	31.6	58.0
		6 inches	29.6	28.0	37.9	54.5	68.7	77.5	83.6	82.0	71.0	60.2	44.1	31.9	55.8
		9 inches	30.0	28.4	35.7	50.8	64.4	73.0	79.4	77.9	70.5	59.0	44.3	33.4	53.9
		12 inches	31.4	29.3	35.0	48.2	60.8	69.5	75.8	75.0	66.6	58.4	45.1	34.8	52.5
		24 inches	35.1	32.9	34.7	44.8	56.5	64.2	70.8	71.6	66.9	59.7	49.5	39.5	52.2
		36 inches	38.1	35.3	35.7	43.0	53.2	61.1	67.5	69.4	66.7	60.7	52.1	43.2	52.2
	LINCOLN, NEBR.														
22	1894–1904*	1 inch	28.2	28.0	40.1	58.7	70.9	79.2	86.9	85.1	73.7	58.1	40.6	31.2	56.7
	1894–1904*	3 inches	38.5	27.8	38.8	57.6	69.7	78.1	85.1	84.0	73.5	59.4	42.7	31.4	56.4
	1894–1904*	6 inches	29.0	28.1	37.4	53.6	66.7	76.1	82.1	80.9	72.0	58.3	42.6	31.7	54.9
	1894, 1898–1904*	9 inches	29.8	28.0	36.0	50.8	64.2	73.7	79.7	78.9	71.0	58.5	38.9	28.8	53.2
	1894–1904*	12 inches	30.2	29.9	35.6	49.1	61.2	69.7	75.8	75.6	69.2	57.9	44.5	34.6	52.8
	1894–1904*	24 inches	35.1	33.1	35.3	45.4	56.9	64.6	70.5	72.0	68.2	60.0	49.2	39.5	52.5
	1894–1904*	36 inches	38.1	35.1	36.0	43.6	53.8	61.5	67.7	69.8	67.9	61.3	51.9	43.0	52.5
	MANHATTAN, KANS.—FURROWS														
23	1914–1919	Surface			28.4	Average for 5 winters from December to February or March.									
		2-inch furrow			28.8										
		4-inch furrow			30.0										
		6-inch furrow			30.2										
	TEMPLE, TEX.														
24	1921–1924	Air	51.5	53.2	59.8	68.0	75.6	83.4	87.1	88.6	79.9	68.7	61.0	54.4	69.3
	1918–1924	1 inch	53.1	52.6	59.4	69.1	78.8	88.6	93.7	93.2	83.8	72.6	59.8	52.6	71.4
	1918–1924	3 inches	53.2	52.3	58.6	67.9	78.3	86.5	92.2	93.3	83.9	73.1	60.2	52.8	71.0
	1918–1924	6 inches	53.3	52.7	58.7	67.5	77.3	85.6	91.7	92.3	83.8	73.3	60.9	53.4	70.9
	1918–1924*	12 inches	54.6	53.5	58.1	65.9	74.9	83.4	87.8	88.9	83.8	74.8	62.9	55.4	70.3
	1918–1924	24 inches	56.9	55.2	58.2	64.8	72.1	78.9	84.2	86.9	83.6	76.3	67.0	59.5	70.3
	1918–1924	36 inches	59.6	57.4	59.0	64.2	70.2	76.4	81.7	84.4	83.3	78.7	71.0	62.9	70.7
	1918–1924	48 inches	61.1	58.9	59.0	63.6	68.7	74.0	79.2	82.2	82.1	79.2	73.2	65.0	70.5

TABLE I.—*Soil temperatures (°F.)*—Continued

BOZEMAN, MONT.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
25	1916–1920	1 foot	29.7	29.1	30.2	35.0	44.2	55.4	64.4	62.9	55.4	44.6	35.4	31.5	43.2
		2 feet	31.8	30.7	31.4	34.8	42.8	52.3	60.0	61.4	56.2	47.0	38.6	34.1	53.4
		3 feet	33.5	32.2	32.0	34.1	40.0	48.7	56.1	58.1	55.1	47.6	39.9	35.6	42.7
		4 feet	36.0	34.4	33.6	34.6	38.8	46.1	53.8	57.3	55.2	49.2	42.8	38.3	43.3
		5 feet	37.7	35.7	34.7	35.3	38.8	44.8	51.0	54.2	53.7	49.8	44.4	40.2	43.4
		7.5 feet	41.2	39.3	37.9	37.4	38.7	42.0	46.6	50.8	51.9	50.0	46.4	43.4	43.8
		10 feet	41.8	39.8	38.5	37.9	38.7	41.7	46.1	50.0	51.4	50.1	46.9	43.9	43.9

MOSCOW, IDAHO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
26	1898, 1899, and 1901 (1901 only in January, February, March, October, November, and December)	1 inch				40.7	49.4	57.1	63.8	63.4	52.7	47.0	38.2	32.2	
		3 inches	30.8	28.8	34.4	41.2	51.2	58.0	64.1	67.5	54.6	47.8	40.8	33.8	46.1
		6 inches	31.8	30.2	34.6	42.9	48.6	56.0	63.6	65.4	56.8	50.5	41.6	34.6	46.4
		9 inches	32.8	31.0	35.0	45.9	48.9	54.8	62.9	64.9	57.5	51.8	42.8	36.4	47.1
		12 inches	38.2	32.8	35.4	44.7	48.4	54.8	62.2	64.3	58.1	52.2	43.6	37.4	47.7
		24 inches	35.8	34.5	36.2	44.5	47.5	52.9	59.2	62.5	58.2	53.2	45.8	39.2	47.5
		36 inches	37.8	36.2	37.0	40.5	46.2	50.1	55.9	60.0	57.8	53.8	48.0	41.6	47.1
		4 feet	39.8	38.0	38.0	40.5	45.4	48.8	53.7	58.1	57.1	53.8	48.8	43.4	47.1
		5 feet	40.8	39.5	38.8	40.6	44.6	47.5	51.8	56.3	56.5	54.0	49.6	44.6	47.0
		6 feet	42.8	40.8	39.6	41.5	44.6	47.1	50.6	54.7	55.5	54.0	51.6	46.2	47.4

FORT COLLINS, COLO.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(27)	1889–1927	3 inches	27.7	29.6	36.5	46.6	56.5	66.7	71.4	69.3	61.1	48.3	36.7	29.7	48.3
		6 inches	29.3	30.6	37.1	47.4	56.6	67.0	71.9	70.4	62.8	50.8	39.0	30.2	49.4
		1 foot	32.8	31.1	36.6	45.5	55.8	65.5	70.9	70.1	63.7	52.3	40.7	33.2	49.8
		2 feet	32.9	32.7	36.8	45.3	53.3	62.5	68.5	68.8	64.0	54.4	43.7	36.5	50.0
		3 feet	35.4	32.6	37.1	43.6	51.1	59.1	65.2	66.6	63.4	55.5	46.0	38.9	49.5
		6 feet	42.5	40.5	40.8	44.2	48.8	54.2	59.2	61.8	62.0	58.0	52.1	46.5	50.9

SANTA CATALINA MOUNTAINS, ARIZ.

Reference No.	Year	Depth	Elevation	Slope	Maximum	Minimum	Range	Mean
			Feet					
(28)	Averages of 18 weekly readings of soil temperatures, summer of 1922	3 inches	9,000	North	59.3	53.1	6.2	56.2
			9,000	South	77.7	61.6	16.1	69.6
			8,000	North	62.4	56.5	5.9	59.4
			8,000	South	82.6	60.9	21.7	71.8
			7,000	North	78.9	50.6	28.3	64.7
			7,000	South	91.9	61.3	30.6	76.6

PULLMAN, WASH.—BLUEGRASS SOD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(29)	April, 1912, to January, 1913	1 inch	31.7			46.5	60.2	62.7	66.0	75.4	60.2	42.0	40.0	33.2	
		2 inches	31.9			45.4	57.8	63.2	65.9	73.2	58.9	42.0	39.9	33.7	
		6 inches	32.3			44.7	54.9	62.3	64.8	70.2	57.2	42.4	40.4	34.5	
		1 foot	32.7			44.8	52.8	62.2	64.9	67.7	56.7	45.0	42.2	36.6	
		2 feet	35.6			44.3	50.6	59.0	62.8	66.5	58.5	48.5	45.0	39.2	
		3 feet	37.5			44.1	48.9	56.3	60.9	64.8	58.9	50.9	47.4	41.9	

PENDLETON, OREG.—DRY, LIGHT SOIL, THIN GRASS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(30)	1890	Air	21.0	30.1	42.0	52.2	60.1	63.0	68.8	68.8	60.0	49.6	40.4		
		4 inches	26.7	37.3	44.9	62.2	72.3	74.2	84.6	83.3	73.2	57.4	45.8		
		8 inches	27.8	35.6	40.9	55.3	66.3	68.4	77.6	75.8	66.5	53.7	43.2		
		12 inches	30.4	37.1	39.8	52.2	63.1	65.8	73.7	73.3	65.7	54.7	45.2		
		24 inches	34.6	38.1	40.1	50.1	60.9	63.7	71.0	71.7	66.7	57.3	48.5		

CORVALLIS, OREG.—WET AND DRY SOILS UNDER ALFALFA AND CLOVER COVERS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(31)	1910	Air							[3] 81.8	[4] 71.9	[2] 71.8				
		3 inches, dry							[3] 80.7	[4] 77.8	[2] 70.5	Average, under alfalfa and clover.			
		3 inches, wet							[3] 76.2	[4] 71.6	[2] 64.5				
		3 inches, dry							[3] 82.0	[4] 77.5	[2] 71.0	Under alfalfa.			
		3 inches, wet							[3] 77.0	[4] 71.8	[2] 64.0				
		3 inches, dry							[3] 79.3	[4] 78.0	[2] 70.0	Under clover.			
		3 inches, wet							[3] 75.5	[4] 71.5	[2] 65.0				

DAVIS, CALIF.—DEEP, RECENT ALLUVIAL SOIL, UNCROPPED

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(32)	February to September, 1925, and January to June, 1927.	Air	44.8	49.9	51.6	54.2	60.3	69.1	75.6	70.8	63.6				
		½ inch	48.0	51.1	58.4	63.2	74.8	82.0	90.6	86.0	77.4				
		3 inches	48.2	49.9	55.2	61.9	72.9	78.9	86.6	83.2	76.4				
		6 inches	48.8	50.2	54.5	60.9	72.0	78.0	87.2	84.5	79.4				
		12 inches	48.5	50.2	53.7	60.2	70.8	76.4	81.4	83.0	77.2				
		24 inches	53.2	51.9	54.6	59.7	68.4	72.9	82.8	82.8	78.2				
		36 inches	51.2	51.4	54.3	60.1	68.8	72.9	80.8	82.5	78.6				

TABLE 2.—*Mean daily ranges—Soil and air temperatures (° F.)*

[Superior figures in figure columns are additional references under "Literature Cited" at end of article]

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
					NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN										
(4)	1926	Air					[21] 14.2	11.1	11.2	10.6	10.7	8.3	[24] 9.6		
		3 inches					[8] 11.6	[29] 13.1	6.4	[30] 11.0	[28] 10.9	6.1	[18] 5.6		
		6 inches					[8] 6.2	[29] 7.4	8.7	[30] 5.8	[27] 6.6	4.4	[17] 3.0		
		9 inches					[9] 3.5	3.5	2.5	[30] 1.9	[28] 2.6	1.4	[19] 1.6		
		12 inches					[9] 1.6	[29] 1.7	1.2	[30] 1.0	[28] 1.3	[30] 1.1	[18] 0.9		
					NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL										
(5)	1924	Air				20.1	17.5								
		6 inches				6.3	6.8								
		12 inches				5.7	6.6								
		18 inches				3.3	2.9								
					NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM										
(6)	1902	Air						[22] 18.9	17.7	20.0	16.9	[28] 16.9	[23] 15.8	[14] 11.2	
		12 inches						[21] 2.6	2.5	[29] 1.4	1.4	1.2	0.9	[21] 1.1	
					ATHENS, GA.—LAND BEDDED UP FOR COTTON										
(8)	1926	Air			26.7	Average from Apr. 22. to May 20.									
		1.5 inches			18.9										
					WOOSTER, OHIO										
(11)	1924 to April, 1925	1 inch	*3.6	5.3	*11.6	*21.8	22.2	23.2	22.9	[18] 17.0		16.9	8.5	4.9	
		6 inches	*1.0	1.2	*3.3	*7.3	7.8	9.0	8.3	[24] 8.4		3.3	2.7	1.5	
					COLUMBUS, OHIO										
(11)	1923	1 inch											[4] 6.9	9.8	
		6 inches											[4] 1.1	[30] 2.5	
					LEXINGTON, KY.										
(12)	1924–1927*	3 inches	1.2	3.2	5.8	7.5	6.2	7.7	8.7	7.1	8.4	6.9	5.1	4.3	6.0
	June, 1928, to June, 1929	4 inches	[21] 2.9	1.0	8.1	[29] 7.6	[24] 6.5	5.7	10.2	[30] 8.2	7.4	6.5	5.5	[30] 3.7	6.1
	1924–1927*	18 inches	0.8	1.6	0.9	1.0	1.0	0.8	0.9	0.8	0.8	1.1	1.0	1.4	1.0
					PURDUE, IND.—CLEAN CULTIVATION WITH WINTER-COVER CROP										
(13)	May, 1913 to May, 1915	6 inches	1.4	5.4	6.7	11.9	10.8	9.2	9.4	8.2	11.7	7.6	10.3	5.2	8.2
					PURDUE, IND.—STRAW MULCH										
(13)	May, 1913, to May, 1915	6 inches	1.8	2.7	1.6	5.3	3.5	3.7	2.6	3.2	4.2	3.8	4.4	3.5	3.4
					PURDUE, IND.—GRASS LAND										
(13)	May, 1913, to May, 1915	6 inches	2.1	4.1	3.8	9.0	9.8	8.7	8.4	6.8	7.4	5.0	7.7	4.7	6.5
					FARGO, N. DAK.—SCIENCE GARDEN										
(18)	1922–1925*	1 inch					27.9	30.2	36.3	43.8	32.9	22.3			
					FARGO, N. DAK.										
(19)	1929–30	Air				*21.8	*24.9	26.6	28.5	25.4					
		½ inch				*8.0	*7.0	9.0	15.9	13.6					

TABLE 3.—*Mean monthly ranges—Soil and air temperatures (° F.)*

NEW HAVEN, CONN.—SANDY LAOM, LEVEL, EXPOSED TO SUN

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(4)	1926	Air					[2] 33.0	37.0	41.0	39.0	35.0	34.0	[14] 37.0		
		3 inches					[8] 27.0	[29] 38.0	38.0	[30] 33.0	[28] 26.0	34.0	[18] 27.0		
		6 inches					[8] 18.0	[29] 26.0	26.0	[30] 21.0	[27] 21.0	27.0	[17] 19.0		
		9 inches					[9] 14.0	16.0	14.0	[30] 15.0	[28] 14.0	15.0	[19] 16.0		
		12 inches					[9] 10.0	[29] 11.0	11.0	[30] 12.0	[28] 12.0	[30] 18.0	[18] 14.0		

NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(6)	1902	Air						[22] 40.5	37.4	37.4	44.8	[28] 43.6	[23] 40.5	[14] 36.9	
		12 inches						[21] 7.2	10.8	[29] 9.0	11.7	13.3	0.9	[21] 2.2	

WOOSTER, OHIO

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(11)	1924 to April, 1925	1 inch	* 17.4	26.7	* 23.2	* 44.4	42.5	42.0	34.5	[18] 30.5		34.5	30.0	28.0	
		6 inches	* 6.8	11.6	* 13.3	* 27.5	23.0	27.5	18.5	[24] 19.0		18.5	19.5	12.5	

COLUMBUS, OHIO

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(11)	1923	1 inch											[4] 10.0	20.0	
		6 inches											[4] 3.5	[30] 1.0	

LEXINGTON, KY.

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(12)	1924–1928*	3 inches	14.5	13.0	26.3	31.7	19.3	18.3	17.2	17.8	16.2	25.5	[27] 28.0	28.5	21.4
	July, 1928, to June 1929	4 inches	[24] 20.5	13.5	37.5	21.0	[21] 16.5	[6] 5.5	[9] 7.0	[30] 29.0	25.5	29.0	29.5	18.5	20.3
	June, 1928 to May, 1929	8 inches	[24] 12.5	8.5	23.0	10.0	[21] 14.0	[19] 9.5	[9] 8.0	[30] 10.5	[20] 16.0	17.0	16.5	13.0	13.2
	1924*–1927*	18 inches	8.3	16.3	11.2	12.3	7.2	9.5	10.2	5.0	10.5	9.5	16.0	12.0	10.7

FARGO, N. DAK.—SCIENCE GARDEN

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(18)	1922–1925*	1 inch					58.9	56.7	60.8	67.0	[3] 38.3	[17] 48.1			

FARGO, N. DAK.

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(19)	1929–30	Air				* 47.0	* 66.2	60.2	62.0	59.0					
		½ inch				* 27.0	* 38.5	30.5	42.5	38.5					

TEMPLE, TEX.

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(24)	1921–1924	Air	59.2	53.8	51.2	45.2	38.5	31.5	31.8	36.0	42.5	54.2	55.0	41.5	45.0
	1918–1924	1 inch	41.4	37.2	39.7	39.6	35.4	37.4	39.3	37.7	42.1	42.5	41.8	41.8	39.7
	1918–1924	3 inches	32.9	30.9	33.9	32.6	30.4	30.8	30.6	29.3	33.3	35.9	35.0	35.1	32.6
	1918–1924	6 inches	28.2	23.5	26.1	25.3	25.3	24.1	23.3	21.7	25.6	29.7	27.1	26.7	25.6
	1918–1924*	12 inches	19.0	16.8	13.8	14.0	15.8	8.9	10.5	7.7	12.6	17.8	15.8	20.7	14.4
	1918–1924	24 inches	11.9	10.5	9.7	8.1	11.5	8.4	5.4	5.5	6.6	10.0	10.5	12.3	9.2
	1918–1924	36 inches	10.1	6.6	4.9	5.8	7.9	6.1	4.1	4.4	4.4	6.6	9.4	10.1	6.7
	1918–1924	48 inches	7.1	6.5	2.8	4.7	6.2	7.0	3.8	3.2	2.6	5.3	7.0	10.8	5.6

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RESOLUTIONS PASSED BY THE POLAR YEAR COMMISSION OF THE INTERNATIONAL METEOROLOGICAL COMMITTEE AT LENINGRAD, AUGUST, 1930 [1]

Upon the invitation of the Academy of Sciences and of the hydrometeorological committee of the Union of Socialist Soviet Republics received through Prof. A. P. Karpinsky, president of the Academy of Sciences, a conference of the International Commission for the Polar Year of 1932–33 was held in Leningrad, August, 26–30, 1930, under the presidency of Dr. D. la Cour. The international commission was represented at this conference by Messrs. D. la Cour (Denmark), H. Dominik (Germany), J. A. Fleming (United States), H. Hergesell (Germany), W. E. W. Jackson (Canada), A. P. Karpinsky (Union of Socialist Soviet Republics), J. Keränen (Finland), Ch. Maurain (France), G. C. Simpson (Great Britain), H. U. Sverdrup (Norway), and A. Wangenheim (Union of Socialist Soviet Republics). There were also present, as the guests of the international commission, Messrs. H. D. Harradon (United States) and V. Laursen (Denmark), and Miss Bruun de Neergaard (Denmark).

The following scientists of the Union of Socialist Republics participated in the sessions of the conference: A. P. Karpinsky, president of the Academy of Sciences and of the Polar Commission of the Union of Socialist Soviet Republics, member of the International Commission for the Polar Year of 1932–33; A. Wangenheim, president of the hydrometeorological committee of the Union of Socialist Soviet Republics, member of the International Commission for the Polar Year of 1932–33; J. Schokalsky, president of the Geographical Society of Russia, corresponding member of the Academy of Sciences, and member of the Polar Commission of the Union of Socialist Republics; L. Rudowitz, chief of the hydrometeorological department of the Hydrographic Office; A. M. Lawrow, member of the Polar Commission of the Union of Socialist Soviet Republics, collaborator of the Hydrographic Office; N. Rose, collaborator of the Central Geophysical Observatory and member of the Polar Commission of the Union of Socialist Soviet Republics; W. N. Obloensky, V. Schuleikin, B. Weinberg, A. Kaminsky, A. Schönrock, W. Arnold-Alabjew, and M. Kartzeff, collaborators of the Central Geophysical Observatory; W. Schostakowitsch, collaborator of the Central Geophysical Observatory, former director of the Geophysical Observatory at Irkutsk; A. Tolmatchew, secretary of the Polar Commission and of the local committee on the Polar Year of the Union of Socialist Soviet Republics, chief of the expedition of the Academy of Sciences of the Union of Socialist Soviet Republics to the region of Petchora; D. Rudnew, member of the Polar Commission of the Union of Socialist Soviet Republics; P. Moltschanow, director of the Aerological Observatory at Sloutzk; Trutnew, director of the Geophysical Observatory at Irkutsk; A. W. Sokolow, collaborator of the hydrometeorological committee of the Union of Socialist Soviet Republics; W. Timonoff, collaborator of the National Hydrological Institute; N. N. Kalitin, director of the Actinometric Institute at Sloutzk; R. Khuzechwili, director of the Magnetic Observatory at Sloutzk; V. Akhmatow, vice director of the Hydrographic Office.

The principal objects of the conference were to receive reports on the actual state of preparation in the various countries for the work of the polar year, the actions taken by the international organizations to support the project, and to consider in more detail the research program which may be accomplished. It appeared from the proceedings and discussions of the conference that unusual interest is being evidenced everywhere in the successful outcome of the plans for the polar year of 1932–33.

As the result of this conference and following discussion of the reports submitted, some 22 resolutions were adopted which are briefly summarized below.

1. The polar year of 1932–33 is designated to begin August 1, 1932, and to continue for 13 months through August 31, 1933, that is, the actual period of recorded observations is not to be less than 13 months.

2. It is desirable that all stations taking part in the program for the polar year zonal time should be used, that is, Greenwich mean time $\pm$ n hours, where n is a whole number.

3. The desirable network of magnetic stations north of 55° latitude recommended is as follows: Lerwick, Shetland Islands; Eskdalemuir, Scotland; Jan Mayen Island; station on east coast and station on west coast of Iceland; Mygbugten, Scoresby Sound, Angmagssalik, Ivigtut, Godthaab, Godhavn, and Thule (Cape York), Greenland; Lady Franklin Bay (Fort Conger), Ellesmere Island; Kingua Fiord, Baffin Island; Chesterfield, Fort Rae, and Meanook, Canada; Sitka and Fairbanks, Alaska; Yellen (East Cape), Nijni Kolymsk, Yakutsk, Bulun, Dickson, and Sverdlovsk, Siberia; Matochin Shar, Novaya Zemlya Island; Hooker Island, Franz Josef Land; Kazan, Kouchino, Kandalaksha, and Sloutzk (Pavlovsk), Union of Socialist Soviet Republic; Petsamo and Sodankylä, Finland; Hammerfest or Bossekop, Kautokeino, Abisko, and Tromsö, Norway; Bear Island; Spitzbergen; Stockholm (Lovö), Sweden; and Copenhagen (Rude Skov), Denmark. (For 21 of these stations definite provision is already made.)

4. The establishment of the magnetic stations proposed by the national committees of various countries but not yet assured, is considered of very great importance for the work of the polar year, and the commission recommends very strongly their establishment.

5. Since a station in Lady Franklin Bay would be located near the station Thule (Cape York, Greenland) but on the opposite side of the magnetic axis of the earth (and between it and the north geographic pole), it is of urgent importance that a magnetic station be established in the vicinity of Lady Franklin Bay.

6. In view of the location of Iceland near the zone of maximum frequency of the aurora, the commission recommends establishing two magnetic stations in Iceland, one toward the west and the other toward the east.

7. It is important that there be a network of magnetic stations also in the Antarctic, which may be furthered through the help of whalers stationed in the Antarctic; there should be especially a station as close as possible to the south magnetic pole.

8. The commission is pleased to note that the Republic of Argentina will collaborate in the polar year at the station in the South Orkneys, and hopes that that Government will renew the old station on New Year's Island.

9. In view of the importance of a knowledge of the magnetic field and of its variation in the vast extent of the oceans, the establishment of magnetic stations on Easter Island, on the island of Tristan da Cunha in the southern Atlantic, and on the Kerguelen Islands in the Indian Ocean is strongly recommended.

10. It is desirable that the special polar year program of magnetic observations be continued as long as possible over the whole world. In the Antarctic the observations should begin if possible half a year before and continue half a year after the polar year as above defined.

11. The commission recommends making magnetic observations with registering apparatus of great speed, according to proposals which will be communicated later.

12. All types of instruments that have not already been used in the polar regions, but which will be used during the polar year, should be tested as soon as possible by actual use at an Arctic station. (The Finnish Government has offered the use of its station and facilities at Sodankylä for this purpose and for the instruction of observers.)

13. It is desirable that the magnetic program of the commission be sent to all the observatories of the world, with the request that each cooperate in following that program; this is especially the case for those observatories situated in regions where there are few observatories.

14. In view of the importance of the researches considered by the commission of all magnetic data relating to the polar regions, catalogues of magnetic determinations in the polar regions pre-

[1] Abstracted by J. A. Fleming and W. J. Peters from the minutes of the meeting supplied by the chairman, D. la Cour. For the resolutions passed at the Copenhagen meeting in September, 1929, at which provision for the Polar Year Commission, 1932-33 was made, see Terr. Mag., 34, 1929 (317-318).

pared by W. J. Peters of the Carnegie Institution of Washington and B. Weinberg of the Central Geophysical Observatory of Leningrad should be published by the Union of Socialist Soviet Republics, if possible, before the polar year.

15. The commission regards the following mountain stations desirable for the execution of the meteorological program: 2 on the west coast, 1 near the southern coast, 2 on the east coast, and 1 on the northeastern coast of Greenland; 2 on Iceland; 1 on Jan Mayen Island; 1 on the Faroe Islands; 2 in Norway; 1 in Spitzbergen; 1 on the Kola Peninsula at Chibiny; 1 at Matochin Shar; 1 in Franz Josef Land; 1 at Boulbouh (Verkhoyansk Mountains); and 1 near Bering Strait.

16. For the execution of the aerological program, five stations around the Arctic are desired and it is recommended that one each be established in Alaska, in Canada, in Greenland, in Spitzbergen, and in the Union of Socialist Soviet Republic.

17. The countries interested in the polar year are requested to arrange for pilot-balloon stations on board as well as for the careful training of the personnel of "selected ships" for aerological and meteorological investigations at sea.

18. It is recommended that the program of investigation of the upper layers of the atmosphere submitted by Professor Moltschanow for the study of the temperature-gradient should be supported by the Union of Socialist Soviet Republics, if in any way possible, with the necessary means.

19. The publication in the protocol of the conference was authorized of Prof. A. Kaminsky's communication on investigation of climate in polar regions with recommendation that his proposition be considered especially in regard to establishing observing stations.

20. Having received the report Hydrological investigations in the period of the International Polar Year and the detailed program in hydrology proposed by the institutions of the Union of Socialist Soviet Republics, the commission considers that program important both from the economic viewpoint and the viewpoint of geophysical science, and directs that these documents be submitted to the subcommittee created to consider the questions of exploring the sea during the polar year.

21. The report from the permanent actinometric commission of the hydrometeorological committee of the Union of Socialist Soviet Republics submitted by Prof. M. N. Kalitin on the organization of the actinometric work during the polar year was accepted with thanks and authority given to publish it in the protocol of the conference.

22. The commission on the higher atmosphere, the commission on clouds, and other international commissions are asked to decide upon and to communicate one year before the beginning of the polar year those dates selected for particular programs of observation, in order that they may be included appropriately in the program of the polar year.

Special committees, which were requested to make their reports by the end of 1930, were appointed to consider and prepare reports upon questions relative to standard equipment, to methods of observing and recording, and to publication. The members of the committees are: Publication, Messrs. Simpson, Sverdrup, and Maurain; magnetic instruments, Messrs. Fleming, la Cour, and Keränen; meterological instruments, Messrs, Simpson and Sverdrup; aerological instruments, Messrs. Hergesell and Wangenheim; actinometric instruments, Messrs. Wangenheim and Dominik; atmospheric-electric instruments, Messrs, Maurain, Hergesell, and la Cour; earth-current instruments, Mr. Fleming; instruments for auroral observation, Messrs. Maurain, la Cour, and Keränen.

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CLIMATOLOGICAL CHARTS FOR THE ALLEGHENY FOREST REGION

By H. F. MOREY

[Allegheny Forest Experiment Station,[1] U. S. Forest Service]

There is a great use for climatological charts in forest research. One of the most frequent uses of such charts is in the study of distribution of forest types and individual tree species. The foundation for the study of the influence of climate on vegetation has been laid by Merriam, Abbe, Livingston, Shreve, among others, and serves as an excellent basis for a more elaborate investigation of any particular region. Bates, at the Lake States Forest Experiment Station, has found that Norway pine in the Lake States, whence comes the bulk of the seed used for artificial reforestation with this species, grows under mean summer temperatures varying only from 56° to 66° F. This is very important from the silvicultural point of view because it has been learned in Sweden that if the variation of the mean summer temperature of a planting site differs by so much as 1° C. (1.8° F.) from that of the seed source, results may be only 65 per cent as good as if home-grown seed had been used. According to Bates, traffic lanes for seed will ultimately be laid along isothermal lines.

Climatological charts of a scale large enough to be useful in regional or local studies are generally available only for the several States. But vegetation recognizes few political boundaries and the Federal forest experiment stations are organized so far as possible on a regional basis. When, therefore, the Allegheny Forest Experiment Station recently undertook to compile charts of precipitation, temperature, and other climatic factors, it was confronted with the task of placing on a single map data from four different States—Delaware, Maryland, New Jersey, and Pennsylvania.

As a result of an inquiry sent to the Weather Bureau section directors of the States concerned and the adjoining States, it was learned that but few charts were available. Virginia and West Virginia had none. The charts procured are listed in Table 1. Summaries "of the climatological data for the United States" were received for all the States.

[1] Acknowledgment: Mr. George S. Bliss, section director, U. S. Weather Bureau, Philadelphia, Pa., gave many helpful suggestions which were followed in the preparation and revision of the charts.

TABLE 1

State	Temperature isotherm interval	Precipitation isohyetal line interval	Growing season days	Frost dates [1]
Delaware	Average annual 1°	Average annual, 2 and 4 inches	Exact average for counties	Exact average for counties.
Maryland	do	do	do	Do.
New Jersey [2]	Mean annual, 1° Mean summer, 1° Mean winter, 1°	Mean annual, 2 inches Mean summer, 2 inches Mean winter, 2 inches	None	None.
New York	Mean annual, 2°	Normal annual, 5 inches	do	Do.
Ohio [3]	Normal annual, 1° Normal monthly, 1°	Normal annual, 3 inches	15-day intervals	5-day intervals.
Pennsylvania [4]	Normal annual, 2° Normal monthly, 2°	Normal annual, 5 inches	do	15-day intervals.

[1] Average date of first killing frost in the spring and average date of last killing frost in the fall.
[2] From the Annual Report of the State Geologist, New Jersey, 1899.
[3] From Alexander, W. H., 1923. A Climatological History of Ohio, Ohio State University. This also included charts for normal monthly distribution of precipitation, and annual snowfall.
[4] From charts furnished by George S. Bliss, section director, at Philadelphia. Charts of normal annual snowfall and normal monthly snowfall were also procured for Pennsylvania.

TABLE 2

Climatic factor	Beech-Birch-Maple [1]	Entire region
Average annual temperature	44° to 49° F.	44 ° to 57° F.
Average dates of last killing frost in spring	4-20 to 6-10 [1]	4-10 to 6-10.
Average dates of first killing frost in fall	9-10 to 10-30 [1]	9-10 to 11-10.
Average length of growing season, days	120 to 165 days	120 to 224 days.
Average summer temperature (June to September, inclusive).	63° to 68° F.	65° to 75° F.
Mean minimum summer temperature (June to September, inclusive).	53° to 55° F.[2]	53° to 67° F.
Mean maximum summer temperature (June to September, inclusive).	74° to 79°F.[3]	74 ° to 85° F.
Average annual precipitation	38 to 50 inches	34 to 50 inches.
Mean summer precipitation (June to September, inclusive).	14 to 19 inches	14 to 20 inches.

[1] General. Few exceptions as noted under factor under consideration. Cities such as Erie and Scranton may have some effect.
[2] Except Scranton (57°) and Erie (60°).
[3] Local variations in Alleghenies to 82°, local climate may vary from that shown on our small scale chart.

Several difficulties arose when an attempt was made to combine the State charts into a regional one. The isotherms and isohyetal lines for one State often failed to connect with the corresponding climatic line in the adjoining State. The base maps of the States were on different scales, and the intervals between the various climatic lines differed. The New Jersey charts were old and did not correspond with the averages of 1920. These differences made it necessary to compile our own regional charts from the data available.

Averages obtained from the summaries "of the climatological data for the United States" were plotted on a large scale map of the region. Average rather than normal values are charted. The distinction between "average" and "normal" is, according to Milham, that average is the "sum of a number of observation divided by the number of observations. If the observations have been extended over a sufficient length of time so that accidental irregularities have been eliminated by taking the average, then the average value may be spoken of as a normal." Where great irregularities were observed, as in some of the shorter records, the data were compared and weighed with data from nearby stations having longer records, according to the method of Reed and Kincer.[1] Topography was used as a guide to the charting of the climatic lines in the mountainous regions. No contour map on a suitable scale was available for the region.

Temperature, precipitation, growing season, and frost charts have been prepared to date, and are presented herewith. The dearth of available drought, humidity, and evaporation data has made it impossible to make charts for these factors.

Several interesting correlations between climate and vegetation have been made with the charts so far prepared. Through the courtesy of the Pennsylvania Department of Forests and Waters [2] a large scale map of the "Beech-birch-maple" type in Pennsylvania was obtained, and the climate of the type as worked out from our charts is given in Table 2.

From the rather sketchy species distribution maps of the Forest Service it has been observed that the southern limit of chestnut oak in Maryland and Delaware practically coincides with the northern limit of loblolly pine. The dividing line roughly follows the 72° average summer isotherm, the 62° mean minimum summer isotherm, and the 82° mean maximum summer isotherm. The average summer precipitation is from 16 to 17 inches. There seems to be no relationship between this dividing line and average annual temperature, average annual precipitation, frost, or growing season, although all of these factors, either singly or collectively, may affect the distribution. Evaporation, humidity, drought, and winter temperature probably play an important part in limiting the northward occurrence of the pine and the southern occurrence of the oak. Loblolly pine has been reported as occurring naturally in Cape May County, but nowhere else in New Jersey. The State forest service, however, has had success in planting loblolly pine in southern New Jersey. That soil is not the chief limiting factor in the distribution of the loblolly pine in New Jersey, is apparent from a study of the soil bulletin for Maryland and New Jersey. Soil types which in New Jersey contain no loblolly pine, have a luxuriant growth of this species in southern Maryland. Unless undetermined chemical or biological differences within the same soil type, in the two States, limit distribution, climate must be the chief limiting factor.

A real knowledge of the climatic conditions of a region, conveniently recorded in the form of charts, is valuable in many less obvious connections. Thus, the fact that cities have an effect upon average temperature, has been revealed in the Allegheny region by our temperature, frost, and growing season charts, and raises a question as to the wisdom of making phenological observations in city parks, a practice at one time considered by the experiment station.

[1] Reed, W. G., and Kincer, J. B., 1917. The Preparation of Precipitation Charts. Mo. Weather Rev. Vol. 45, pp. 233-235.

[2] Illick, Joseph S., and Frontz, Leroy, 1928. The Beech-Birch-Maple Type. Pennsylvania Department of Forests and Waters. Bull. 46.

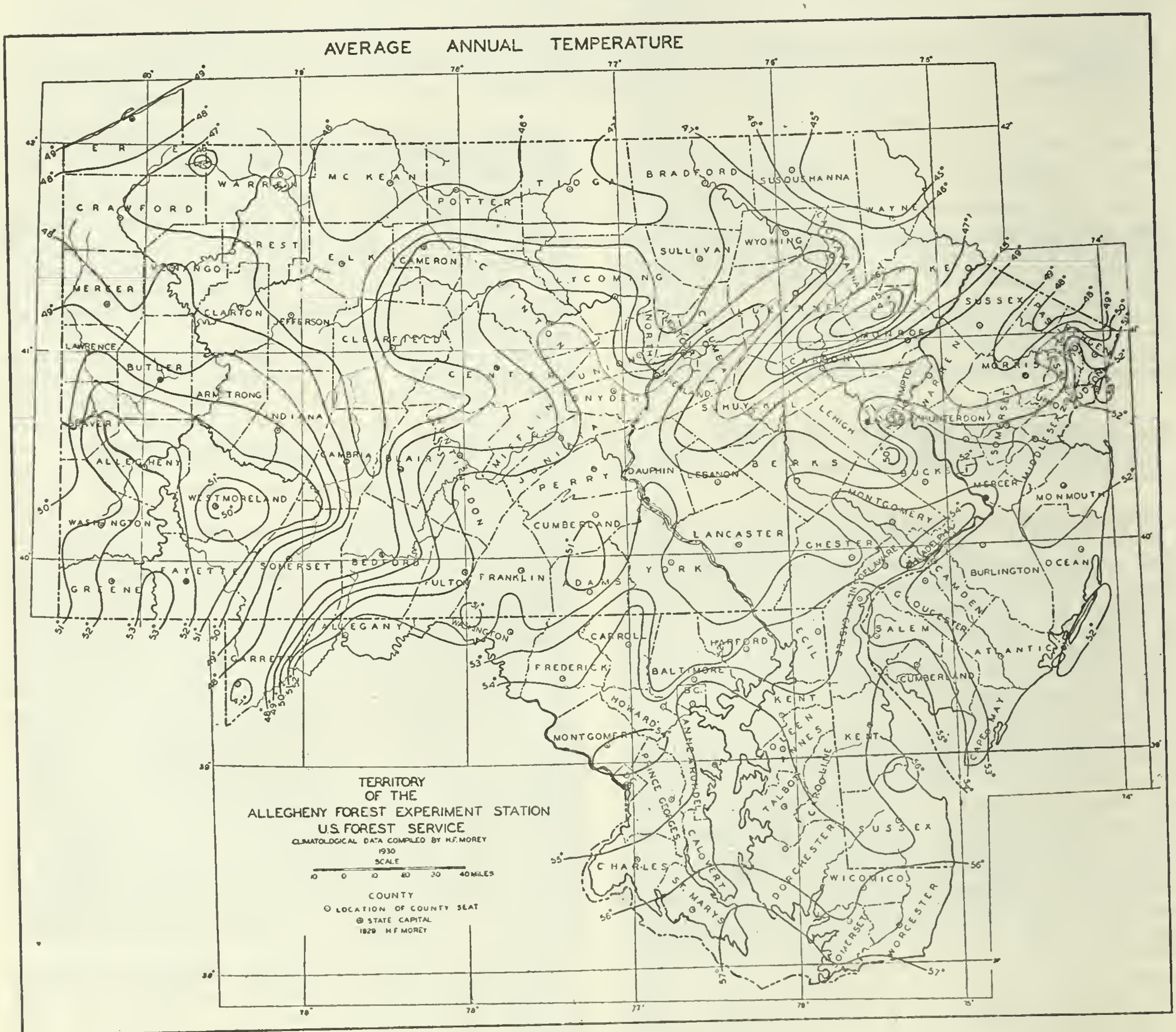

FIGURE 1.—Average annual temperature

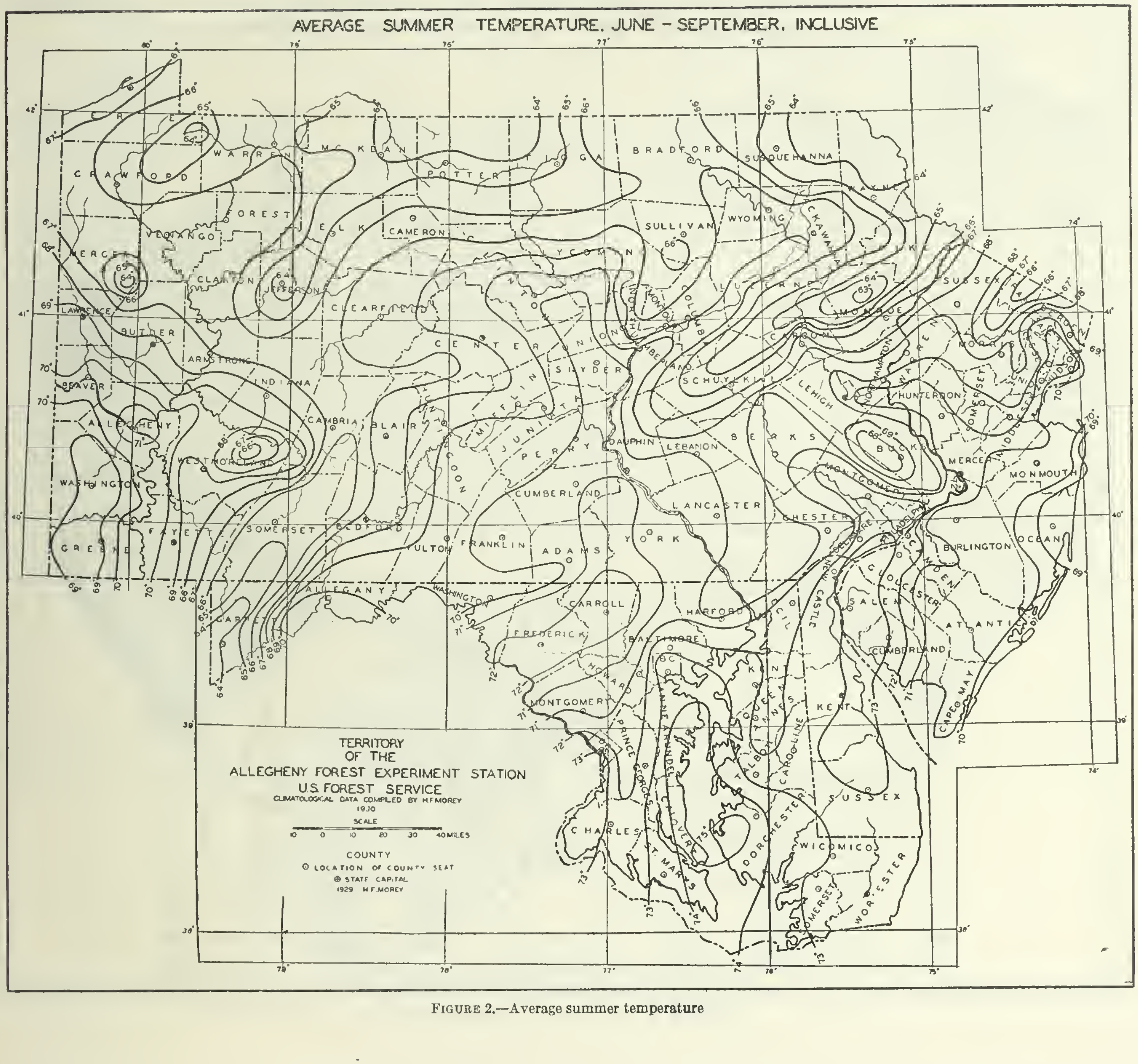

FIGURE 2.—Average summer temperature

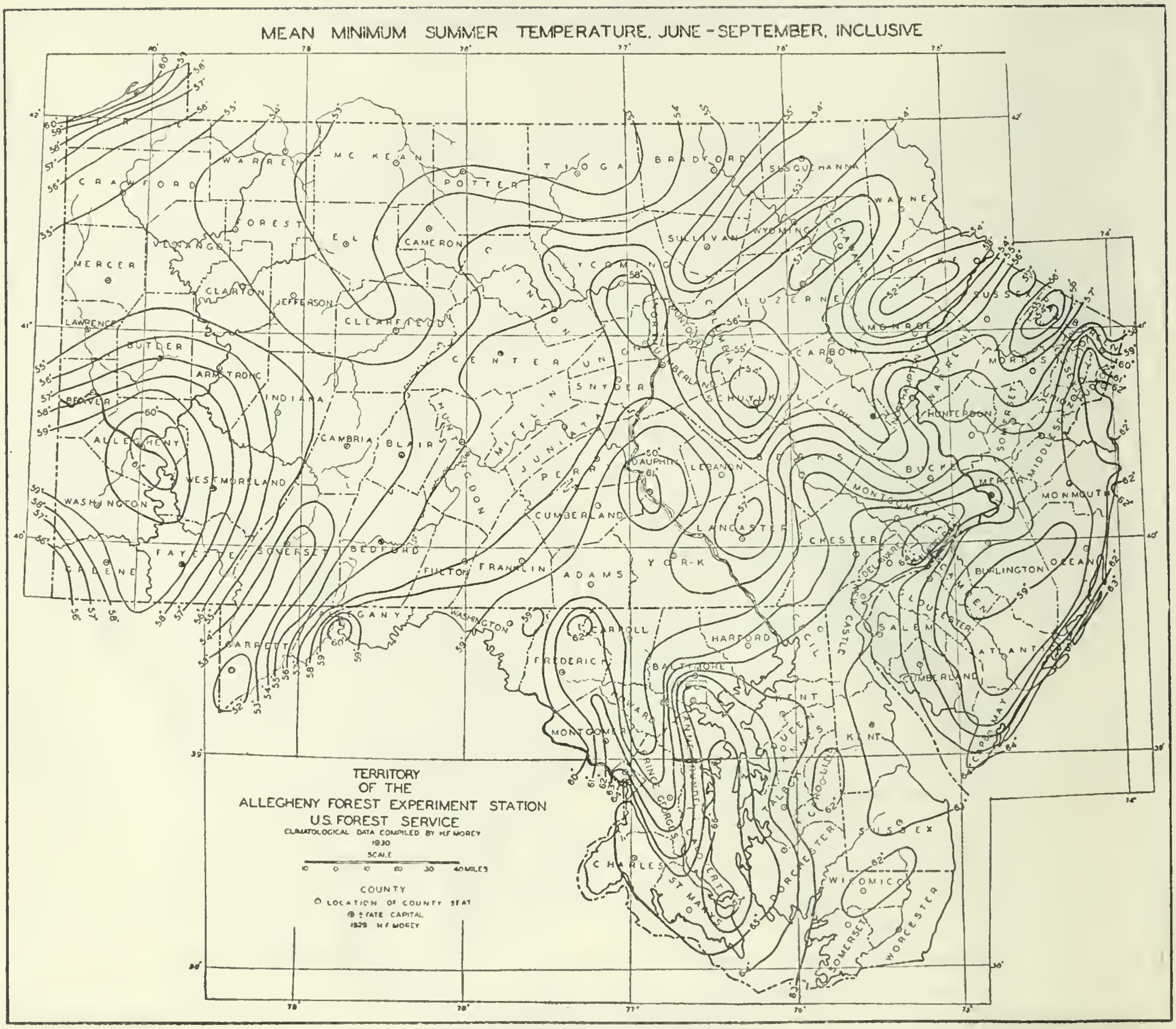

FIGURE 3.—Average summer minimum temperature

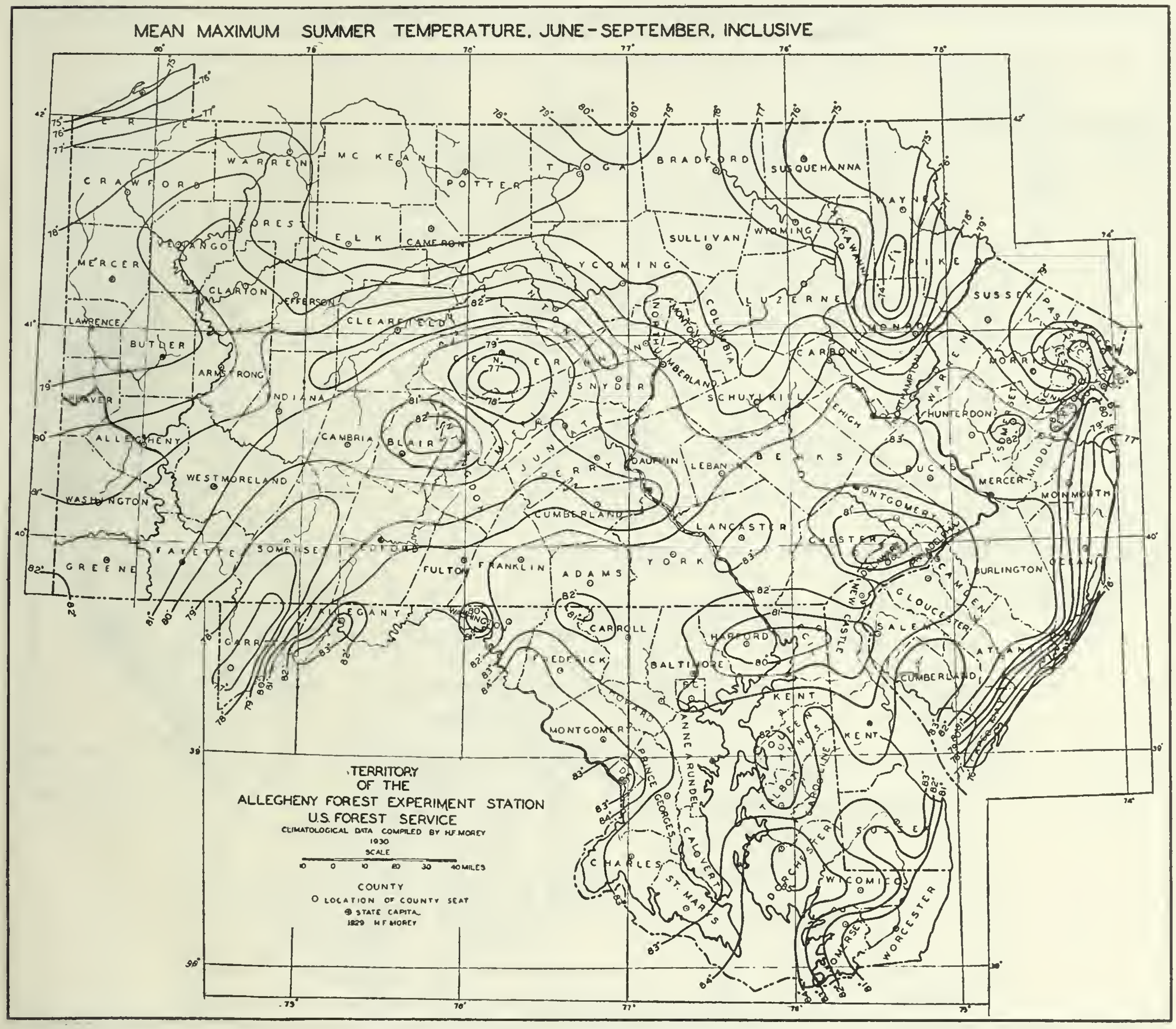

Figure 4.—Average summer maximum temperature

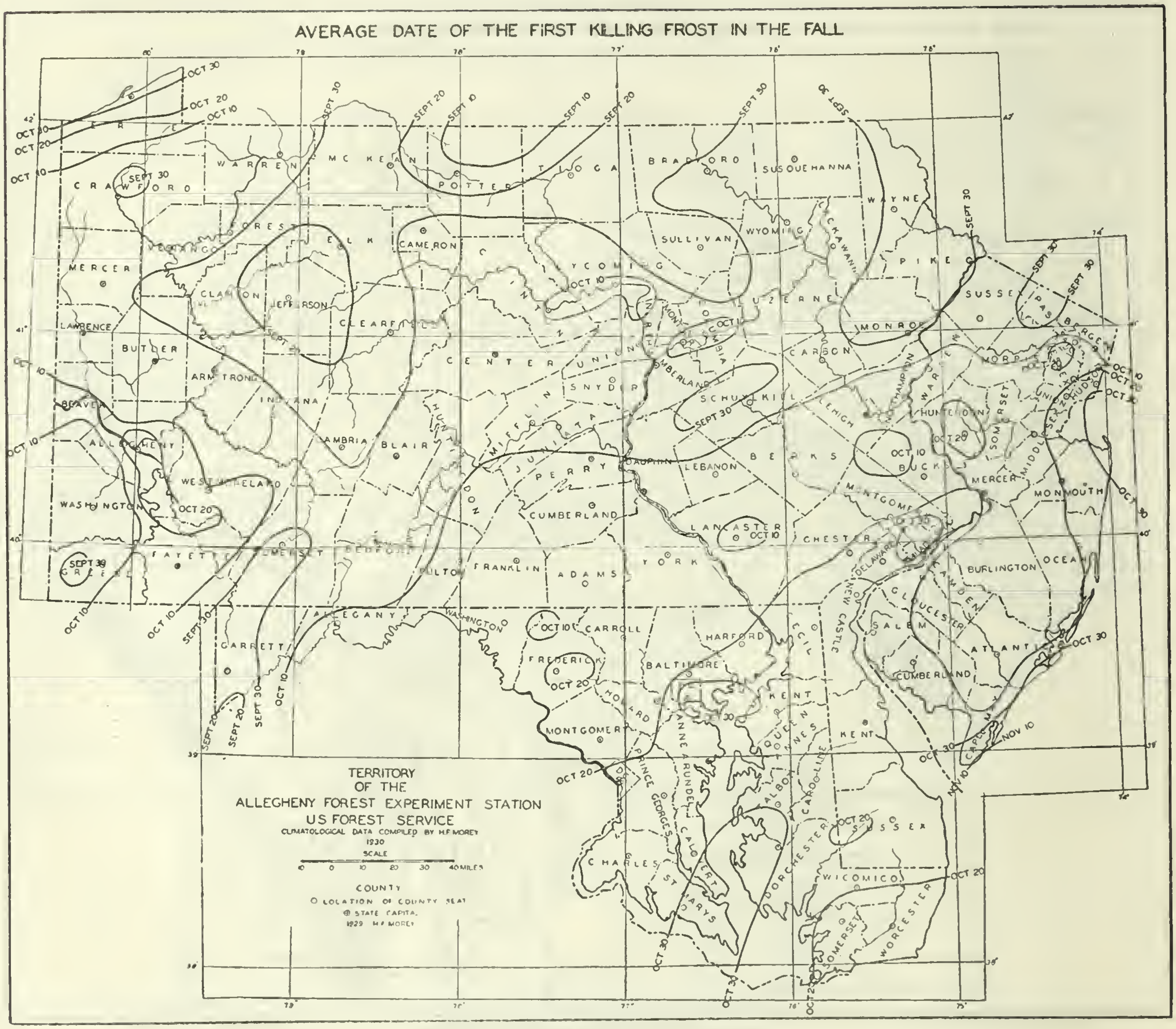

FIGURE 5.—Average date of first killing frost in fall

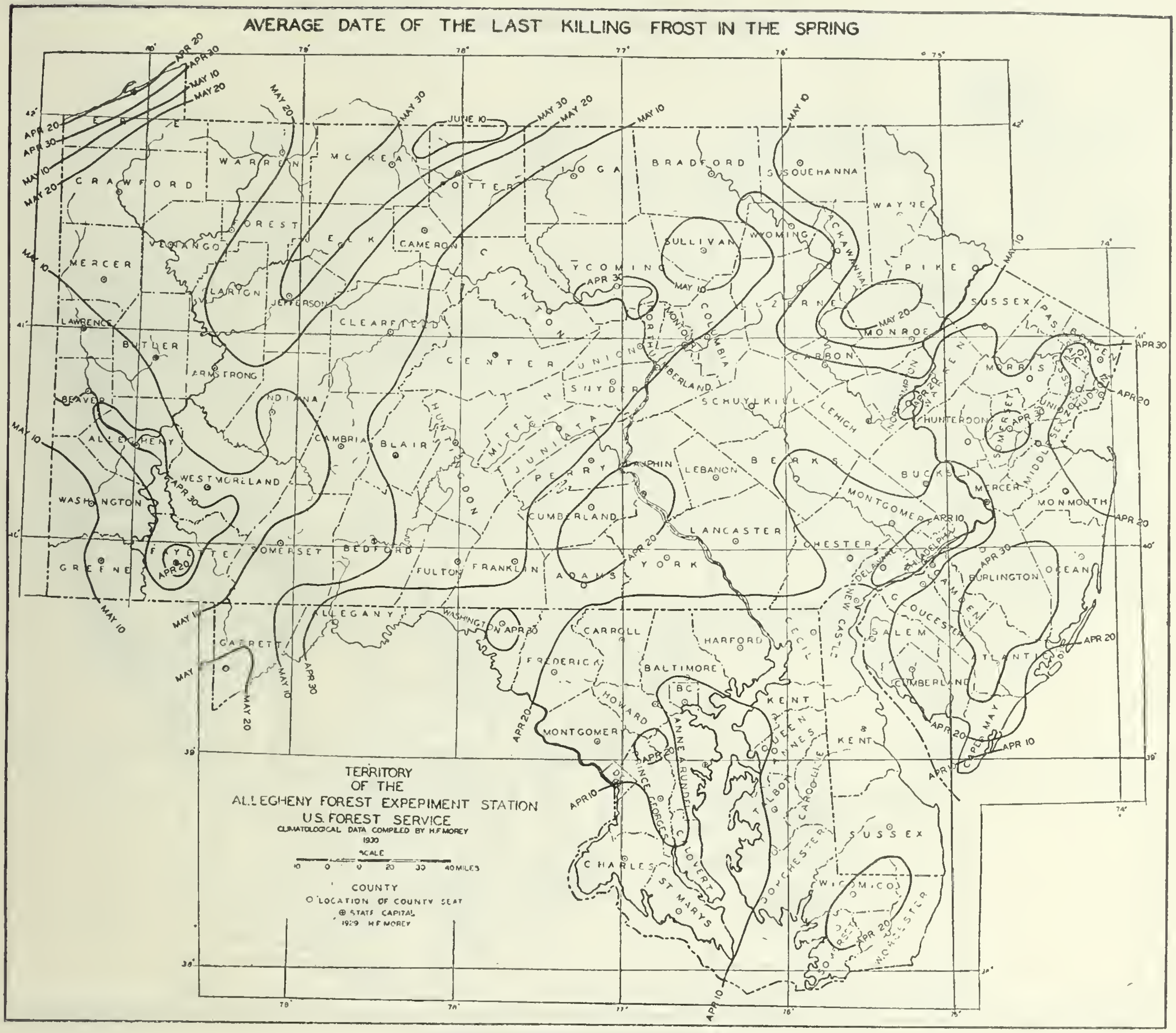

FIGURE 6.—Average date of last killing frost in spring

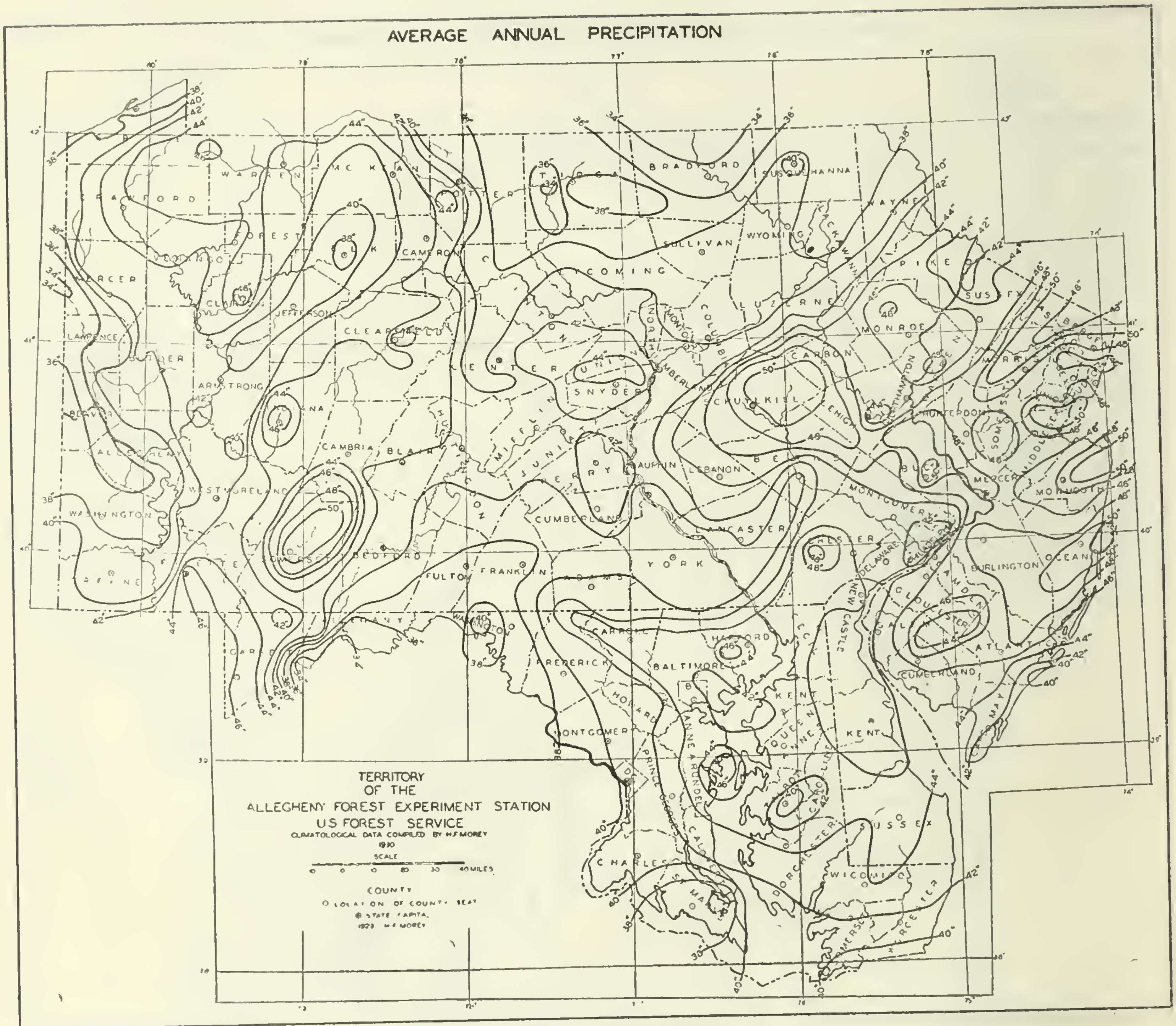

FIGURE 7.—Average annual precipitation

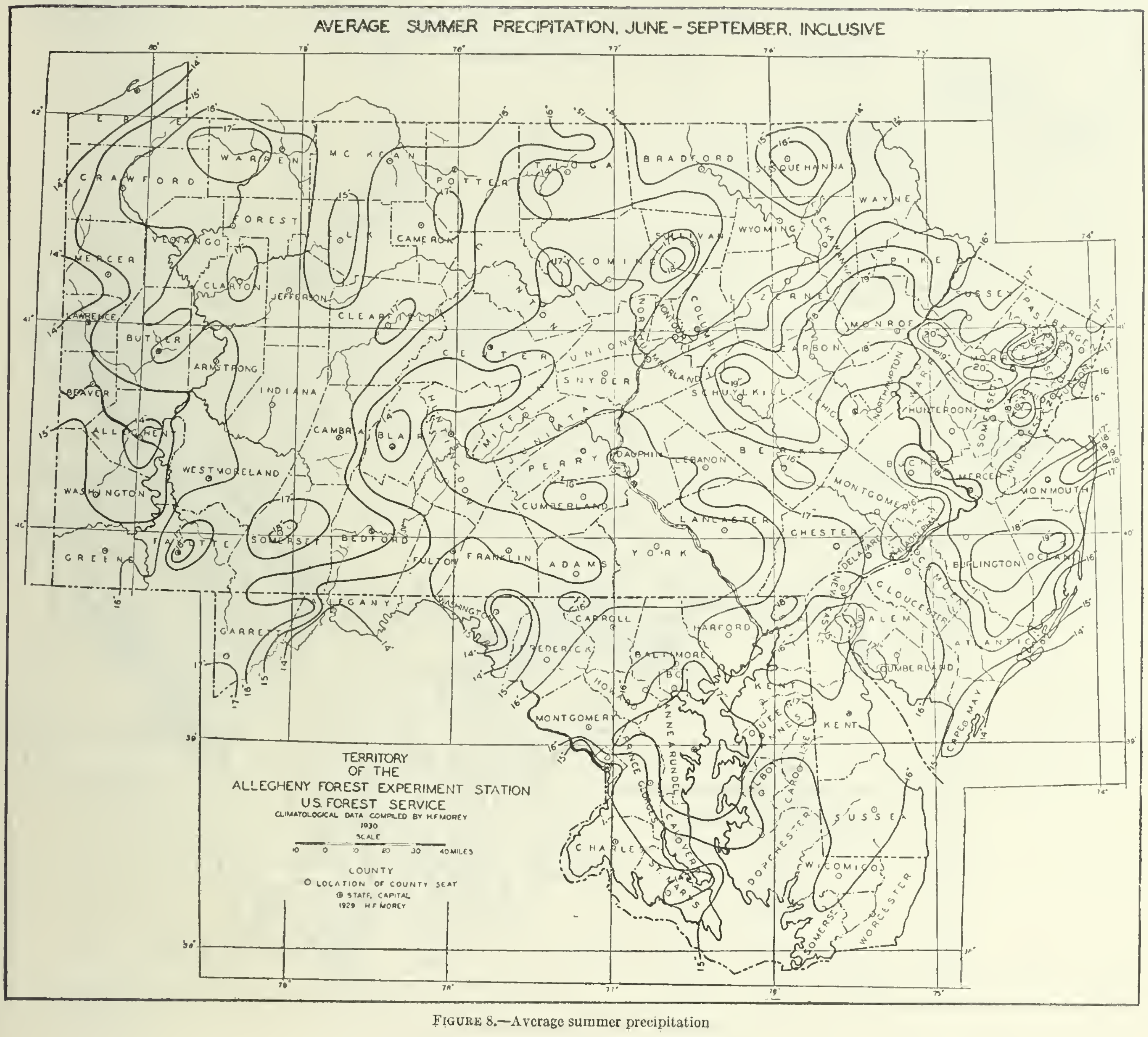

FIGURE 8.—Average summer precipitation

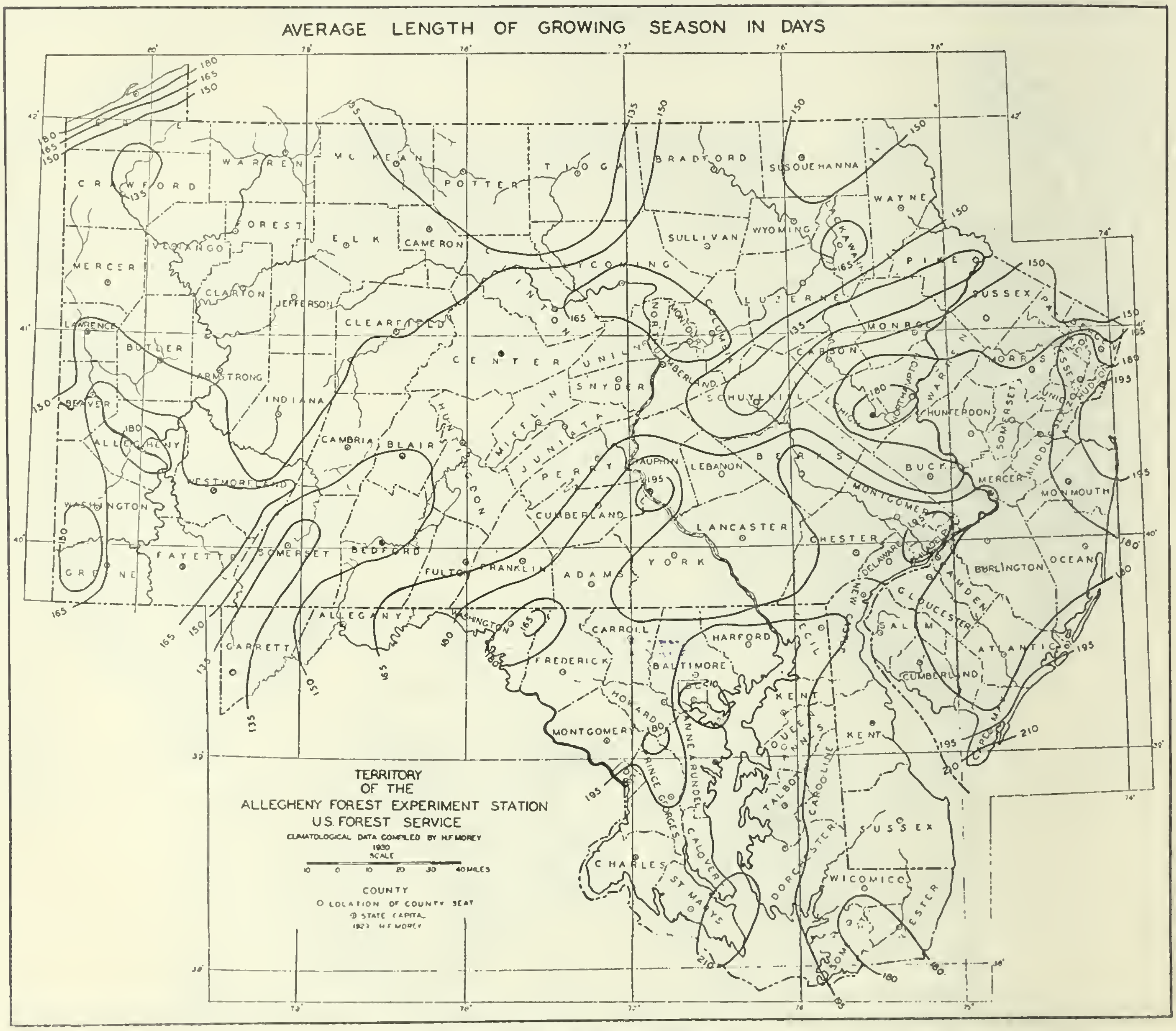

FIGURE 9.—Average length of growing season

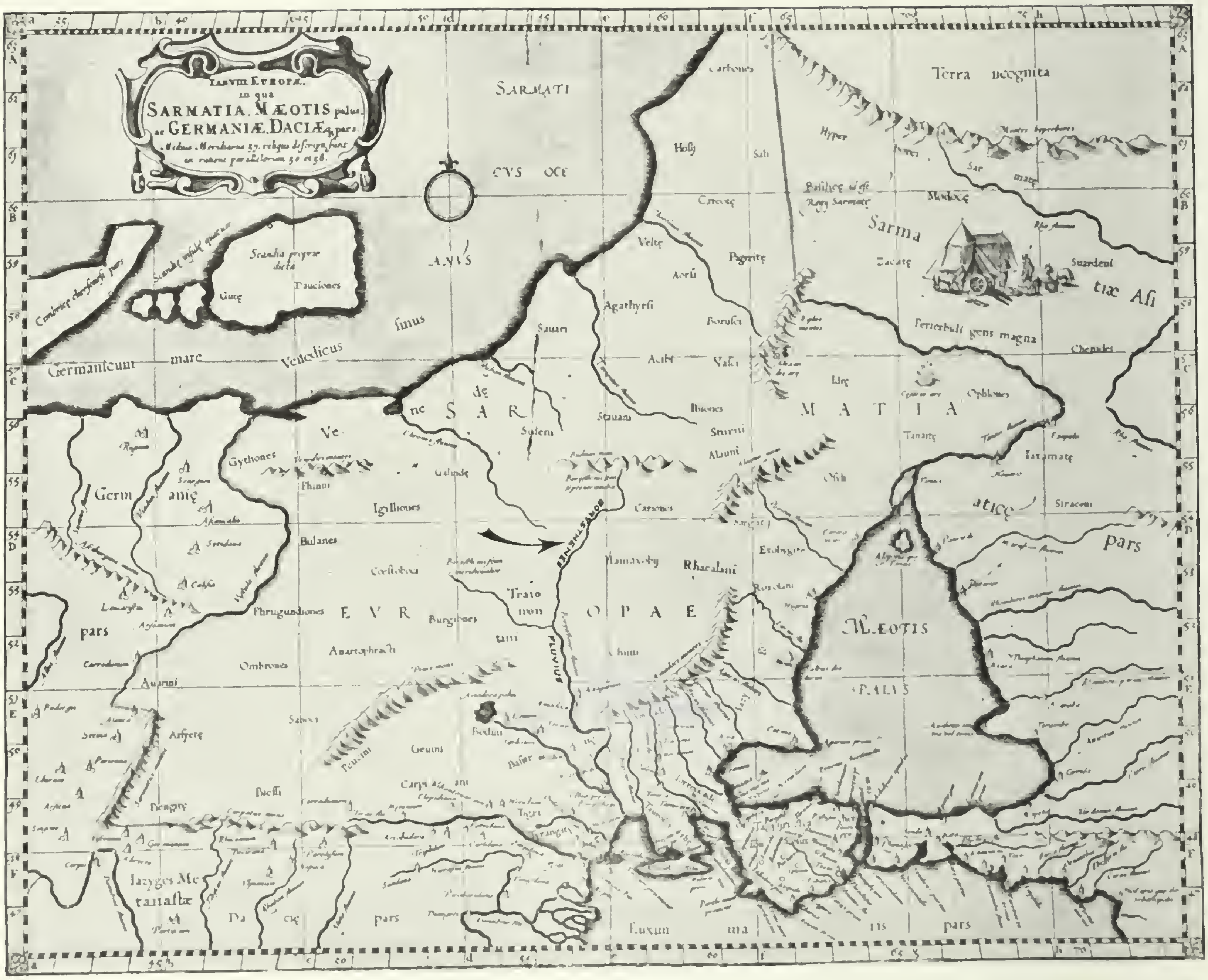

FIGURE 1.—Ptolemy's map, A. D. 150, showing Dnieper River (Borysthenes)

THE FLOW OF THE DNIEPER RIVER

By A. STREIFF, C. E.

[Jackson, Mich., January 29, 1931]

The Dnieper is the third largest river on the European continent. It was well known in antiquity, as shown on Ptolemy's map from his Geographica, A. D. 150. (Fig. 1.) The ancient Greeks named the great stream Borysthenes, after a Greek city located near the mouth on the north shore of the Euxine (Black Sea), a colony of Miletus in Asia Minor. Named Danapris by the Romans, Uzi-Uzu by the Turks, Eksi by the Tartars, Lerene by Contarini (1437), and Luosen by Baptista di Genoa (1514), its great drainage basin has been the stage of momentous scenes in history. Napoleon's armies perished while crossing the Beresina, one of its tributaries.

At present one of the great power stations of the world is under construction on this river by the Moscow Government, in consultation with Col. Hugh L. Cooper, builder of the Muscle Shoals and other large power dams. The dam is located in 47° 49′ north latitude and 35° 8′ east longitude. The backwater curve extends over a distance of 150 kilometers upstream. This great work is based on an exhaustive study made by Professor Alexandrov (**1**) from which the following data are taken.

The drainage area of the Dnieper above the rapids is 460,000 square kilometers. The average rainfall on the drainage basin is 540 millimeters (21.3 inches) per year. The average yearly run-off is 110 millimeters (4.3 inches) over a 40-year period, or 20.2 per cent of the rainfall. The mean annual temperature is 8.6 C. Snow cover is usually insignificant, hence the soil freezes to about 1.7 meters in depth.

The whole drainage area is practically level; near the lower reaches the river breaks through the granites and gneisses of ancient proterozoic formation and drops about 37 meters over a length of 150 kilometers.

The discharges of the Dnieper in the rapids are recorded at the long-established gaging station, Lotsmanskaja Kamenka, situated between the upper extremities of the rapids and the mouth of the Samara River. Daily discharges were computed for 49 years and special attention was given to the discharge under ice cover. These were analyzed as shown in Figure 2.

In this graph the discharge is resolved into the Clough cycle and a residual; the sum of both is equal to the original hydrograph.

It may be seen that the Clough cycle averages 28.5 months, or closely equal to the average value evaluated by Mr. Clough (**2**). This cycle varies the flow from 100 to 900 cubic meters per second between maximum and minimum of the cycle. Subtracting the Clough cycle from the hydrograph, the residual curve is obtained, which shows some remarkable characteristics.

The Wolf (11-year) cycle is at once plainly visible, and apparently culminates during the maxima of the Wolf numbers. Superimposed on this Wolf cycle is the Horton cycle of 5.5 to 6 years, so-called after R. E. Horton, who first discovered this cycle in stream flow in the year 1898 (**3**). The maxima and minima of the Horton cycle coincide with the maxima and minima of the Wolf numbers in a remarkable manner.

In its correlations with the Wolf numbers the chart compares very favorably with the records from the Great Lakes region in North America. The maxima of flow agree with both the maxima and minima of the Wolf numbers with neither lead nor lag, constituting the best example of this relation which the writer thus far has found.

The watershed is part of the great plains of Russia, and this confirms that the above-named relations are very pronounced in the continental plains, but show greater dispersion in mountainous regions. The flow of the Danube River near Florisdorf, draining the Austrian and Bavarian Alps, does not show a marked correlation. It seems that the presence of mountain chains has a tendency to disturb the general circulation of the atmosphere, and with it the sequence of precipitation and run-off. Also on the North American Continent do the flow records show the same characteristics.

The difference between the maxima and minima of the Wolf and Horton cycles (combined) is as much as 1,000 cubic meters per second. The flow during maxima is up to 80 per cent greater than the flow during minima.

Here again the vast difference between meteorological and hydrometric data is demonstrated. The difference

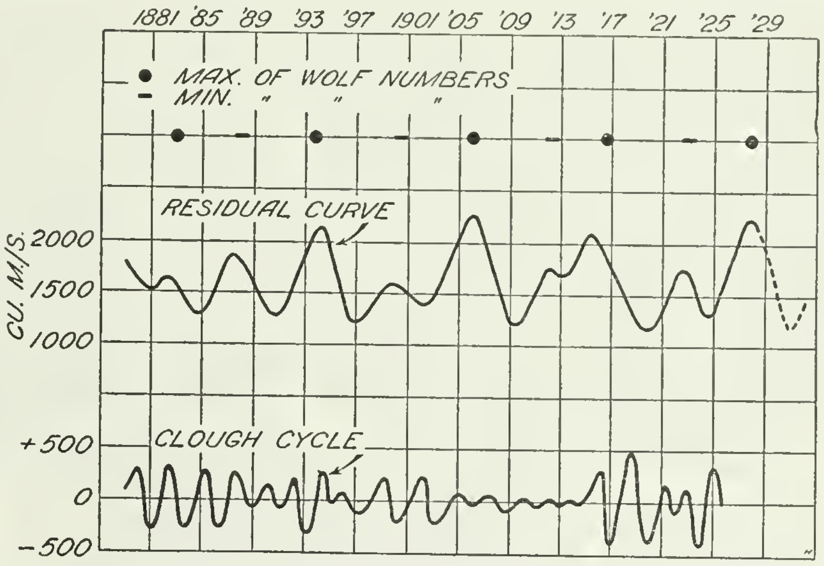

FIGURE 2—Flow of Dnieper River. From data furnished by Professor Alexandrov; Dnieprostroy project

in temperature due to the Wolf cycle is less than 1° C. (**4**), but the flow of this river varies as much as 80 per cent due to some unknown agency apparently in unison with the Wolf cycle (**5**).

As to the prognostication of future flow, it may be seen that 1931 should be a dry year on the Dnieper. The exact period of 22.6 years, or Brückner cycle (**5**) is here between minima fairly well confirmed in the stream flow. The distances between the minima of flow of the residual curve are 22, 24, 22, 23, 22 years, average 22.6 years. This should bring the next minimum in 1931. The low river stages will be favorable for the completion of the great Dnieprostroy dam and powerplant.

In explanation of the name Brückner cycle for the 22.6-year period, whereas it usually is supposed to have a length of 35 years, it may be referred to a previous article in the October, 1929 issue of the MONTHLY WEATHER REVIEW.

More can be concluded from the data shown as to future expectations. The next maximum will probably occur in 1935, and a high maximum in 1940. The amplitude of the Brückner cycle (not shown) is estimated at 350 cubic meters per second. Referring to Figure 3,

page 408 (5) the mean flow should reach a level toward the period 1945–1950 which may be 500 cubic meters per second greater than the present long-term average. The increase in the general mean of 1,600 cubic meters per second would amount to as much as 31 per cent. This latter estimate is necessarily uncertain and depends on the expectation that the "secular" cycle will repeat itself in the future with similar amplitudes as in the past. Accurate records are too short to conclude this with the same degree of probability as is possible in the case of the Horton cycle.

Thus the great Borysthenes of the anicent Greeks demonstrates the apparently close relations between variations in streamflow and the solar cycle. The records on which the above investigation is based were obtained by courtesy of Mlle. T. Maretsky, chief hydrologist, Nijne Dnieper, Moscow, Union of Socialist Soviet Republics.

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SANDSTORMS IN TEXAS

By JOHN A. RILEY

[Weather Bureau, Dallas, Tex.]

Large volumes of sand and dust are occasionally raised by the wind in dry weather over the western plains of the United States. These storms are of three distinct types: (*a*) Strong winds blowing across the plains sometimes attain gale force over a wide area and pick up large quantities of dust, particularly in late winter and early spring when the ground is bare and especially over cultivated land. Such winds attain their highest velocities during the day. (*b*) The second type is the whirlwind, very local and of minor importance; these whirls, sometimes called "sand devils," occur on hot summer afternoons when the lapse rate equals or exceeds the adiabatic. From an airplane they can be seen for miles and easily avoided. (*c*) The most spectacular storms appear to form along the wind-shift line of a barometric trough; they may therefore be expected when cyclonic activity is at a maximum.

Figure 1 shows a sandstorm approaching Big Spring, Tex., on the afternoon of September 14, 1930. It occurred in an elongated LOW that moved eastward across Texas on that date. The trough of low pressure extended at least from the Rio Grande Valley to northern Kansas. At 10 a. m. (ninetieth meridian time) there was a moderate sandstorm at Abilene, with a 20-mile south wind, and thunderstorms were occurring near Wichita Falls, Tex., Oklahoma City, Okla., and Springfield, Mo. At 1 p. m. there were fresh southerly winds from central Texas to Kansas and moderate northerly winds in the Panhandle and west Texas. At 4 p. m. Amarillo reported "moderate sand storm since 1 p. m.," and thunderstorm activity continued in the northern end of the trough, in Missouri. At 7 p. m. scattered thunderstorms were reported from the middle Rio Grande Valley to Kansas and Missouri.

The exact time of the Big Spring storm is not known, but judging from the shadows cast by the sun in Figure 1, it was approaching from a westerly direction at about 4 p. m. The sun was obscured in the second exposure and it was getting much darker in the third, due to the approach of the wall of dust.

Typical of the dry atmospheric conditions in west Texas, the temperature at 7 p. m. at El Paso was 86 and the dew point, 17; at Amarillo, 78 and 35, and at Abilene, 94 and 34. These conditions give rise to "dry squalls" in the semiarid plains of the West—a sudden shift of the wind through 90° or more generally from a southwesterly to a northwesterly direction. The speed of the wind in some of these dry squalls at times reaches gale force and is very gusty. In more humid regions these wind shifts are accompanied by thunderstorms and line squalls.

While the dry squalls do not usually equal in violence the line squalls of humid regions they are always very turbulent and at times violent. Except for the dust they may be practically invisible to the pilot in the air. Pilot J. G. Ingram relates that a few years ago he was flying across a wind shift in west Texas, when the ship dropped a thousand feet and was then carried up above its previous level, accompanied by violent turbulence. Pilot Homer Rader, flying between Dallas and El Paso, passed over a dry wind shift in west Texas late in 1930. From an altitude of 5,000 feet the ship settled slowly at first and then ran into a really violent windstorm, without rain or clouds. The ship was carried up 1,500 to 2,000 feet and dropped a like amount. The air was so rough that control of the ship was at times taken from him, and to relieve the strain the ship was allowed partly to adjust itself to the shock of the variable movements of the air.

Severe sandstorms for more than a short time are unusual, and flights are seldom canceled because of them, for, although the visibility may be zero at times, the dust comes in waves with the gusts of wind, and during the lulls the visibility improves enough for flight.

At times the sand drifts along the ground like drifting snow obscuring the ground but not rising to any great extent. Dust enough to interfere with visibility occasionally rises to 10,000 feet or higher, but it is more likely to be below 6,000 feet so that the pilot can climb above it. At other times the dust rises in columns like cumulus clouds and the pilot can fly around it.

The downward draft of a strong wind blowing across a mountain range often has a focus where it strikes the ground in the lee of the mountain, raising a layer of dust as well as making landing dangerous on account of the currents which are extremely variable in direction and force.

The following notes on sandstorms are furnished by Mr. W. H. Green, Weather Bureau official at Abilene, Tex.

Most of our sandstorms occur with moderately high westerly winds, being rather severe when the wind reaches 33 miles or above. They seem to be most severe when the wind is from west-northwest. High winds from other directions sometimes cause considerable dust but usually precede thunderstorms and are therefore of short duration.

The severity of the sandstorm depends to a very great extent on whether or not the ground is bare or covered with vegetation

(To face p. 30)

FIGURE 1.—Sand storm approaching Big Spring, Tex. Photo by Bradshaw

even considerably more than on the current rainfall. We are not bothered much with sandstorms when the rainfall is normal or above and reasonably well distributed (some exceptions, however), while we occasionally have rather severe sand or dust storms a few hours after a heavy local rain.

The extent of the sandstorm is probably about the same as the extent of the high winds and the bare ground. I have personally seen much worse sandstorms on the plains of Texas, around Plainview, than I have seen in this vicinity; and Abilene people, who have occasion to be in El Paso at the same time that we have a sandstorm in this vicinity, occasionally come back and report that "New Mexico and Arizona both passed through El Paso the day before."

The visibility in a sandstorm varies, of course, with the intensity: In extreme cases it is perhaps not over 100 feet for a few minutes at a time, 300 feet for 30 minutes to an hour, not much over a quarter mile for 2 or 3 hours, and perhaps one-half mile for 4 or 5 hours. The most severe sandstorms occur in the day time, and are sometimes rather severe from about 9 or 10 a. m. to about 7 or 8 p. m.

Most of the sandstorms occur during February, March, and April, these months usually being comparatively dry, until after the middle of April, and the ground usually being bare or almost so, especially that in cultivation, until about the 1st of May, except an occasional year when considerable small grain is planted.

The Big Spring sandstorm bears a striking resemblance, as was pointed out by Prof. A. J. Henry, to the haboobs of the Egyptian Sudan, a photograph of which was reproduced in the Quarterly Journal of the Royal Meteorological Society January, 1925, with an account by L. J. Sutton. Sutton states that the haboob is a dense mass of whirling sand usually accompanied by a strong wind, but he does not clearly distinguish it from other sandstorms. Col. H. G. Lyons, commenting on Sutton's paper, suggests the similarity between haboobs and line-squalls. The haboobs he had experienced appeared as a front of violent upward and downward currents, in which the most striking feature was a mass of dust often thick enough to cause extreme darkness. Lyons thought the term should not include very strong dust-carrying storm, but be limited to circular storms which occur during periods of atmospheric instability. Haboobs in Nubia, he observes, usually come from the southeast and as they pass the wind veers round quickly to northwest, the sky clears and it is definitely colder.

Similar conditions have been noted by pilots in west Texas; shortly after the worst of a sandstorm had passed a cold layer of air near the ground was found to be overrun by a warm layer at about a thousand feet. It appears, therefore, that there is more than a superficial resemblance between the haboob and the Big Spring storm.

THE FOREST FIRE-WEATHER SERVICE IN THE LAKE STATES

By J. R. LLOYD[1]

[Weather Bureau, Chicago, Ill.]

It is doubtful if the average person grasps the enormity of the waste that has been, and is still being caused, in our great forests, which form a large portion of our northern woodlands. In order to acquire a true conception of the situation it is necessary for one to travel through the forests, noting the extent of the areas burned over and the damage that has been done, and to study forest fire statistics.

While no fires of really great extent have occurred in the Lake States in late years, the great Minnesota fire of October 12, 1918, stands out as an example of what might happen again if it were not for the eternal vigilance of the fire protection organizations; and there are times, when weather conditions go against them, that they are almost helpless. This great conflagration was the result of several factors operating in unison. The summer of 1918 in Minnesota was dry and warm, causing the grasses and other small vegetation on the forest floor to dry out and die much earlier than usual. This was followed by a dry autumn, which increased the fire hazard tremendously. Minnesota has much swamp land, and most of the swamps are filled with peat. There are more than 5,000,000 acres of peat land in Minnesota, of which a large portion had been drained prior to 1918.

Therefore, when the drouth of that year developed these peat lands dried out and became the chief source of trouble. Fire in peat is exceedingly difficult to extinguish. Some peat fires have been known to burn from one summer to another, even under a heavy covering of snow during the intervening winter. It so happened in 1918 that the State Forest Service of Minnesota lacked sufficient funds to meet this emergency, due largely to political dissension among State officials and legislators. This was exceedingly unfortunate. Many small fires were started in the peat lands that were not extinguished because of this lack of funds and personnel. These fires smouldered along until there came a day, October 12, with clear sky, low relative humidity, mild temperature and, fresh southwest winds. Then these smouldering fires spread, picked up momentum, merged into one great fire—the greatest of record in this country—and swept on, destroying nearly every living thing in its path. It traveled at great speed, and created winds powerful enough to pull up by the roots large trees. It swept over nearly a million acres in one afternoon and the early part of the following night, snuffed out the lives of nearly 1,000 human beings, killed thousands of domestic and game animals and birds, and destroyed probably $75,000,000 worth of forests and property. The city of Duluth had a very narrow escape, being saved principally by a high range of hills in the rear that parallel the shores of the lake and the bay. This great conflagration is mentioned as an example of what can happen in the northern woodlands when weather conditions are just right.

Since weather conditions play a major rôle in forest fire protection and suppression, it therefore follows that if the forest protective organizations know what to expect in weather for even a day or two in advance that they will be in a position to act on a given situation to better advantage. Therefore, the fire-weather service in the Lake States was created to supply a demand, voiced by the fire protection organizations, for weather forecasts and other weather information that might help them in combatting this red scourge that has cost so many millions of dollars in money, and taken so many thousands of lives of human beings and denizens of the wild.

The project was started in Minnesota during the summer of 1926. From a modest beginning in 1926 the service has been gradually expanded. It was organized in Wis-

[1] In charge fire-weather project in the Lake States.

consin and upper Michigan in 1927 and 1928, and in lower Michigan in 1928. It now covers all of the principal forested lands in the three States, embracing nearly 60,000,000 acres. There are now 33 substations scattered throughout the fire-weather district. These substations are the eyes of the service, so to speak. Most of them are located at the headquarters offices of the State district rangers and wardens, and are about 40 to 60 miles apart from each other. Each station is equipped with a maximum and a minimum thermometer, a rain gage, a sling psychrometer, and an anemometer, and some of them are supplied with hygrographs. Observations are made three times a day, at 8 a. m., noon, and 5 p. m., central standard time, and are usually begun about the 1st of April and continued until about the 31st of October. The headquarters of the service is now located at Chicago, having been transferred from Duluth, Minn., on November 1, 1928.

During the fire season about 25 selected fire-weather stations telegraph reports to Chicago once a day, immediately following the 8 a. m. observation. These reports show what kind of weather has prevailed during the 24-hour period ending at 8 a. m., and give an estimate made by the observer of the degree of fire hazard existing in the forest in the vicinity of the station. The data from these reports are entered on a special outline map, and give a good birds-eye view of conditions existing throughout the district. Particular attention is given to the relative humidity, in connection with the temperature, sunshine, wind movement and rainfall. All these elements are factors in evaporation, and consequently in fire hazard. It may be readily seen that estimation of the degree of fire hazard existing at a given time, and an estimate of what it will be one or two days in advance is a very complicated problem. Not only do the weather factors have to be considered, but thought has to be given to the condition of the forest fuels, which are gradually changing throughout the season, and which are many and variable in kind and character. No single instrument has yet been devised that will give a reliable estimate of the degree of existing hazard. The duff hygrometer, an instrument devised to measure the moisture content of duff and litter on the forest floor has not proved to be successful. The evaporimeter does not give a good index either, since the evaporation that is measured by it is produced in an artificial manner that is not comparable to the manner in which evaporation takes place from forest fuels. Therefore, estimation of existing hazard is largely a matter of personal judgment formed after considering all of the factors involved, and opinions may vary considerably between two or more individuals on a given condition.

When the daily fire-weather reports are received and entered on the map and it is indicated that fire-weather warnings are in order, warnings are made and dispatched to the men in the field as soon as possible, usually about 9.30 a. m. A typical warning as issued for the field would read about as follows:

> Fair Friday and probably Saturday; temperature near 90°; humidity 25 to 35 per cent; gentle to moderate southerly winds becoming southwest by Saturday; high to extreme hazard.

Warnings are telegraphed to sections only where the fire hazard so warrants, and as a rule, the State district rangers and wardens, the superintendents of the State forests, and the supervisors of the national forests are the persons that receive them. Warnings are telegraphed to about 55 points scattered throughout the forested area. The men that receive these warnings by telegraph relay them by telephone to their principal assistants in the field, so that all of the men that have charge of fire protection and suppression work are supplied with this information. The warnings also are broadcast by radio from several stations in or near the forested regions, and are printed in several newspapers as well.

Although particular attention has been given to relative humidity in determining fire hazard, it is doubtful if relative humidity is a more important factor in this connection than temperature. It seems that pioneers in fire-weather investigation, even up to the present time, have overstressed the importance of relative humidity in proportion to temperature in estimating fire hazard. The writer has recently performed some research work in this connection to determine the relationship of relative humidity and temperature to the inception of forest fires. This investigation disclosed the fact that relative humidity and temperature bear practically equal weight on fire hazard, and that these two factors are embodied in the depression of the wet-bulb thermometer of a whirled psychrometer in such a manner that the fire hazard seems to be directly proportional to the change in the wet-bulb depression, other factors being equal. This throws into discard the theory that fire hazard is proportional to the change in depression of the dew point, an idea that seemed to be substantiated by preliminary investigation.

Inception of forest fires, when plotted on a graph against relative humidity, temperature and depression of the wet bulb, have a well defined range. Out of 2,000 fires plotted it was found that only one fire started with temperature below 39°, and that none started when the relative humidity was above 80 per cent. It is also a fact that not a single fire broke out when the wet-bulb depression was below 4°, and that all the fires had started by the time a wet-bulb depression of 26° was reached. The investigation indicated that the wet-bulb depression scale may be divided arbitrarily into rather definite zones of hazard. However, these zones of hazard, being predicated on average conditions, would naturally not apply all of the time. Higher than ordinary wind velocities and periods of drouth would tend to augment the hazard, while on the other hand, appreciable rainfall would tend to lower it, resulting in a shifting of the zones to higher and lower positions on the wet-bulb depression scale.

The fire-weather forecasts are based largely upon the daily manuscript weather maps and the auxiliary pressure change and temperature change charts. There are several types of weather maps that may give rise to high fire hazard, but the most striking type is the one with a HIGH centered west or northwest of the fire-weather district and moving southeastward, followed by a LOW that moves eastward along the Canadian boundary or a little to the northward thereof. This type of map usually gives the lowest relative humidity, and is quite common in spring, April and May, when usually the lowest relative humidity readings occur. The relative humidity usually runs low within the confines of these HIGHS as they pass over the fire-weather district, and when they move in such a manner as to place the center of the HIGHS over the middle Mississippi and the Ohio valleys during the daytime, they often produce extremely low relative humidity readings on the days when such circumstances occur. Relative humidity readings as low as 11 per cent have been noted in May in Minnesota, and readings in the twenties are not at all uncommon in all three States under such conditions. These low relative humidity values are undoubtedly brought about by pressure conditions that allow rapid night radiation of temperature, followed the next day by a rapid rise, thus producing a great range in temperature during the day, and consequently unusually low relative

humidity. Diurnal ranges in temperature of 45° to 50° have been noted in the forested areas of the north when favorable pressure distribution prevails.

As a rule, more forest fires occur in the spring than during any other season of the year, due to the fact that there is then a plentiful supply of dead vegetation on the ground; the days are long, allowing much sunshine; the deciduous trees are leafless or nearly so, allowing the sunshine to strike the forest fuels and dry them out quickly; the relative humidity is at its lowest; and finally, there is usually plenty of wind movement to help dry out the fuels and fan the flames, once a fire is started. However, the year of 1930 proved an exception to the rule in this respect. The long, hot drouth in August and September caused an unusually severe summer fire season that was much more severe than the preceding spring fire season. Michigan and Wisconsin experienced this year one of the worst summer fire seasons, if not the worst, in the history of their respective forest services. The fall fire season is short, as a rule, due to the fact that the days are short and the nights are cold. The relative humidity may be low during the middle of the day in autumn, but only for a few hours, and it is nearly always high then at night, which, with the low night temperatures, is sufficient to either extinguish most ordinary fires, or to check them to such an extent that they may be easily extinguished. The forest rangers say that a cold night is worth the services of 100 or more men in putting out a big fire. While the fall fire season is short and usually less severe than the spring season, it is a singular fact that most of the great conflagrations of the north have occurred in autumn. However, these great fires have always followed drouthy summers.

Fire protection in the Lake States is a problem that has to do largely with care exercised by man; therefore, to a large degree, it is an educational problem. Ninety-nine per cent of all forest fires that occur in the Lake States are man-caused, either directly or indirectly. The other one per cent is caused by lightning. There are areas in the Western States where 35 to 50 per cent of the fires are caused by lightning, thereby creating a very difficult problem; but the number of lightning fires in the Lake States is so small that lightning is given no consideration in the forecasts. The number of fires that occur in the Lake States annually is very large, but of course varies considerably from year to year, depending on the weather. During 1929 about 6,500 fires occurred in these States, burning over about 450,000 acres. This year's totals are not yet available, but it appears that there were probably as many as 7,500 fires that burned over more than a half million acres. Such is the heavy toll exacted by fire, man's greatest friend, it has been said, but perhaps at the same time his greatest enemy.

AIRPLANE LANDINGS IN GUSTY SURFACE WINDS

By PAUL A. MILLER

[Weather Bureau Airport Station, Bolling Field, D. C.]

When surface winds are moving at velocities over 25 miles per hour considerable difficulty is often encountered in landing an airplane. During such times the air currents moving along the surface are considerably retarded by friction, while a few feet above the surface the flow is unhindered. This results in a turbulent condition near the surface, which makes a treacherous landing support for an airfoil passing through it, especially if the wind is gusty.

An airplane landing in still air is glided down within about 2 feet of the ground, where it is leveled off. Flying along level with the motor cut off, it soon loses speed and support. However, it is kept from falling by gradually raising the nose, which presents the airfoil surfaces, at a larger and larger angle to the air, with consequent very gradually decreasing support, but rapidly lessening speed. Presently the speed is so low that the airfoils, no matter what their angle, can no longer fully support the plane, and it settles slowly to the ground in a 3-point landing, i. e., the wheels and the tailskid touch at the same instant. During this time, since the air is still, it has not been necessary to correct for the lateral or longitudinal position of the plane.

How different the case where a strong, gusty surface wind is present. Long experience then becomes necessary to make a good landing, for the plane is buffeted, raised, or dropped unceasingly, and the pilot must have the delicate touch and feel to anticipate and overcome the hazards before they place the plane in a perilous position. If the plane is kept in the proper position to make a landing in still air, the landing will be extremely hazardous. For, if the plane is glided down at normal speed, it will encounter gusts and vertical currents which will raise it, drop it, or throw it over on one wing. Also when leveling off to land, the pilot does not dare to lose much flying speed, for he must have positive control to overcome gusts, and this can be maintained only with an excess of flying speed. For instance, an ordinary mail plane, well loaded, usually lands with an air speed of about 55 miles per hour. Now, if a 30-mile wind is blowing, the plane will land with a ground speed of about 25 miles per hour. Let us assume that the pilot intends to land in the manner used in still air and that he is leveled off and just ready to touch the surface. A sudden gust raises the wind velocity temporarily to 40 miles per hour, giving the plane an actual air speed of 65 miles per hour, and at the large angle the airfoils now present, the plane will suddenly be lifted to a height of 10 or 15 feet. The gust passes, leaving the plane stalled, as the gust has also taken a part of the plane's forward speed. Now, if the pilot has not quickly speeded up the engine and put the nose down in order to gain air speed the plane will actually fall to the ground, with considerable damage to it and a bad shaking up or worse for the pilot. Complicate this situation during landing with the fact that there may be rather violent vertical currents present, which will throw the plane over on one wing or raise or drop it suddenly, and it will readily be seen that under conditions of gusty winds a landing can not be made in the normal manner with any degree of assurance.

Under such conditions, most pilots of experience bring the plane in with an excess of flying speed, probably 10 or 15 miles per hour over the normal speed. Then if the plane is thrown into an abnormal position, the controls have a quick action and the plane can be righted quickly. However, with this excess of flying speed, the plane will not settle to the ground, but must actually be flown down until the wheels touch the surface, it being understood, of course, that the excess speed is gained by nosing down at a steeper angle than normally rather than by the use of the engine. When the wheels touch, the tail is kept up in flying position, which causes the airfoils to present a small

angle of attack to sudden gusts. The plane is kept in the position until considerable speed is lost and the tail drops of its own accord due to lack of support. The weight of the plane and its lower speed then make it practically independent of further gusts.

It can be seen from the foregoing that a knowledge of the prevalence of gusty winds at landing areas is of vital necessity if safe landings are to be made. From a meteorological viewpoint, the occurrence of winds that will cause dangerous landing conditions can be forecast with considerable accuracy. While this is being done more and more as time goes on, there is still room for considerable improvement in the knowledge of local areas where landings are dangerous in gusty weather. Surveys of various terminal airports to determine the areas of maximum turbulence in various winds are becoming a necessity with the increase of passenger flying now occurring. A survey of this kind would give the meteorologist the knowledge necessary to advise the pilot in the air of the gusty condition prevalent and the best landing area on the airport. This advice would be especially helpful at night when landing passenger planes, and would constitute another safety factor to aviation in general.

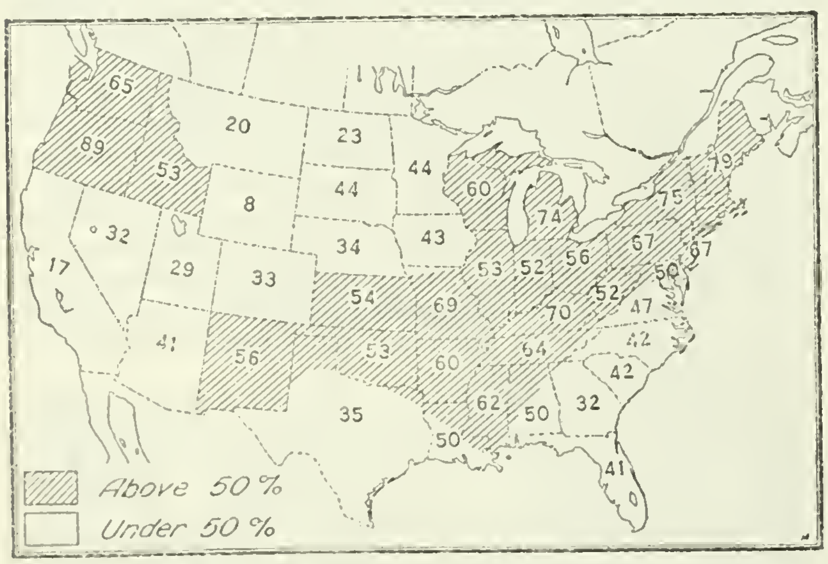
As an illustration of the value of being forewarned of the prevalence of such conditions, the following instance is cited. During January, 1929, a large area of low pressure passed over the middle Western States followed by a rather intense northwestern high. This pressure distribution caused extremely high, gusty surface winds along the Kansas City-Chicago Airway. Winds aloft were also extremely strong, reaching velocities of over 70 miles per hour. A mail pilot took off at Kansas City for the afternoon trip to Chicago, carrying one passenger. The pilot found when he was aloft that it was necessary to crab the plane into the northwest wind at an angle of over 45° in order to remain on the course. The air was so rough that at times they would drop 300 feet and then be driven upward the same amount, both actions being so violent that the wings vibrated alarmingly. The landing lights in the wings were shaken loose and hung in the air stream, banging against the wing with such force as to threaten to tear the tips off. After a 4-hour fight they arrived over Moline Airport, where red landing flares had been put out to advise them that a landing was dangerous. However, the ship was almost out of fuel and a landing had to be made. Wind velocties, as shown by the airport anemometer, were regularly over 40 miles per hour and during gusts reached as high as 58 miles per hour. Through the forethought of the field manager, an ambulance and fire truck had been summoned to take care of any contingencies that might arise in attempting to make a landing. The pilot circled the field and came into the wind, where he found that it was necessay to keep the engine almost wide open to make progress against it. He nosed the ship down and gradually lost altitude. When nearing the fence a sudden gust struck the ship, forcing one wing down until it was almost vertical, but it had sufficient air speed to overcome this and was quickly brought to normal. The pilot then actually flew the ship to the ground, where with its slow ground speed it stopped almost at once. He experienced great difficulty in taxying up to the shelter of a hangar, as with the least access of speed the ship wanted to take off again. However, his previous knowledge of the landing conditions prevailing, combined with his long experience, had enabled him to make a safe landing where none was thought possible.

RELATIONS BETWEEN WINTER TEMPERATURE AND PRECIPITATION

By THOMAS ARTHUR BLAIR

[Weather Bureau, Lincoln, Nebr., Jan. 2, 1931]

What is the relation between winter temperature and winter precipitation in the United States? The lowest temperatures of winter generally occur with fair weather near the center of an anticyclone. The heaviest winter precipitation usually falls with mild or moderate temper-



atures. May we assume, then, that as a rule warm winters are wet and cold winters dry. The following table and chart are an attempt to answer that question.

The data were taken from the tables of comparative State means printed in the annual summaries of climatological data by each section center. They are for the three winter months, December, January, and February, and only those years are counted in which the average temperature departure was $\pm 2°$ F, or more. Table I, in which the States are arranged by regions, gives for each State or section the number of times departures of temperature and precipitation were of like sign and of unlike sign and the percentage of the total having like signs. The percentages are entered by States on the chart, and areas where the percentage is greater than 50 are shaded.

In the shaded areas warm and wet winters are likely to occur together and cold and dry winters together. The presumption that the winters will occur in this way is strongest in Oregon, Michigan, New York, and New England. In these States three-fourths of the winters averaging 2° F. warmer or colder than normal have precipitation departures in the same sense. On the other hand, the chances are better than even that warm winters will be dry and cold winters wet in the South Atlantic States, Texas, the western upper Mississippi Valley, the Missouri Valley, the Rocky Mountain region from Colorado northward, the southern Plateau States, and California. They occur in this association nine times out of 10 in Wyoming, more than three times out of four in California, Montana, and North Dakota, and two times out of three in Nevada, Utah, Colorado, and Georgia.

The area of percentages above 50, which extends northeastward from New Mexico to the Great Lakes

and New England, is obviously associated with the winter cyclones which appear in the southwest and move northeastward. Rain and warm weather occur in their path and snow and cold weather to the northwest. At Dubuque, Iowa, it was found [1] that precipitation in winter occurs more frequently with falling temperature than with rising. In the Plateau and Pacific States the well-known relation between precipitation and the latitudinal position of cyclones as they approach the coast is evident, especially in the marked contrast between Oregon and California. Northern LOWS are attended by warm and wet weather in Oregon and warm and dry in California; southern LOWS by cool and dry weather in Oregon and cool and wet in California. These statements are, of course, incomplete and partial and serve only to illustrate the relations suggested by the chart. It is beyond the scope of this note to enter into a discussion of the conditions under which winter precipitation occurs in the various States and sections of the country. The sole object has been to compile and present the facts of record, expressed in State averages, showing the relationship between winter temperature and precipitation departures.

TABLE 1.—*Number of times winter temperature and precipitation departures were of like and unlike signs. Only those winters were counted in which the average temperature departure for the three months, December, January, and February, was ±2° F. or more*

States	Departures of—		Percentage having like signs
	Like signs	Unlike signs	
North Atlantic:			
New England	15	4	79
New York	15	5	75
Pennsylvania	14	7	67
New Jersey	12	6	67
Maryland and Delaware	8	8	50
Sums	64	30	68
South Atlantic:			
Virginia	9	10	47
North Carolina	8	11	42
South Carolina	8	11	42
Georgia	7	15	32
Florida	7	10	41
Sums	39	57	41

[1] T. A. Blair, Local Forecast Studies—Winter Precipitation, M. W. R., 52: 79–85.

TABLE 1.—*Number of times winter temperature and precipitation departures were of like and unlike signs. Only those winters were counted in which the average temperature departure for the three months, December, January, and February, was ±2° F. or more*—Continued

States	Departures of—		Percentage having like signs
	Like signs	Unlike signs	
Lake region, Ohio Valley, and eastern Mississippi Valley:			
Michigan	14	5	74
West Virginia	11	10	52
Ohio	15	12	56
Indiana	13	12	52
Kentucky	14	6	70
Wisconsin	12	8	60
Illinois	19	17	53
Tennessee	16	9	64
Alabama	12	12	50
Mississippi	13	8	62
Sums	139	99	58
West Gulf:			
Louisiana	9	9	50
Texas	6	11	35
Sums	15	20	43
Central Plains and middle Mississippi Valley:			
Missouri	18	8	69
Kansas	13	11	54
Oklahoma	9	8	53
Arkansas	9	6	60
Sums	49	33	60
Western upper Mississippi Valley, Missouri Valley, and Rocky Mountain:			
Iowa	18	24	43
Minnesota	11	14	44
North Dakota	5	17	23
South Dakota	11	14	44
Nebraksa	12	23	34
New Mexico	10	8	56
Colorado	6	12	33
Wyoming	1	11	8
Montana	4	16	20
Idaho	9	8	53
Sums	87	147	37
South Plateau and south Pacific:			
Nevada	6	13	32
Utah	5	12	29
Arizona	7	10	41
California	1	5	17
Sums	19	40	32
North Pacific:			
Oregon	17	2	89
Washington	13	7	65
Sums	30	9	77

INTERPOLATION OF RAINFALL DATA BY THE METHOD OF CORRELATION

ERIC R. MILLER

[Weather Bureau, Madison, Wis.]

The object of this paper is to apply to a climatological problem a method already well established in other sciences. Suppose that it is wished to interpolate from observations at near-by stations the monthly rainfall at a station where observations have been taken previously. I shall use the symbol Y to refer to rainfalls at the first, X, at the others, y and x to refer to deviations from the mean rainfalls.

Think of a "scatter diagram" each point of which represents the simultaneous rainfalls, X measured on a horizontal scale, Y on a vertical scale. The "regression line" of the statistician (6, p. 120) has the property that the sum of the squares of the distances of the dots of the scatter diagram measured parallel to the Y axis from the regression line, is less than from any other line. Hence, under a least-squares criterion of approximation, the regression line is the "best" representation of the relation between Y and X for all amounts of rain. The following remarks will be restricted to straight regression lines, but the fitting of curved regression lines is also practiced.

The formation of the regression equation, representing algebraically the regression line, involves calculation of the standard deviations of the observed X's and Y's, and their coefficient of correlation. Concise examples of this are given in books on statistics (8, p. 178–179), (6, p. 123) and the calculation is easily carried out with the aid of Crelle's Tables (1).

Horton (3) has given some correlation coefficients calculating from 12 months taken at random. In order to ascertain the effect of change of season upon the correlation coefficient, I have calculated it for the 32 years (1897–1928) rainfall at Waupaca and Pine River, Wis. (14 miles apart), for January, when practically all rain falls in "general" storms for May, the wettest month, with many heavy thunderstorms, and for August, a month characterized by very local rain and drought.

The results were:

	January	May	August
Correlation coefficient	0.94±0.014	0.92±0.018	0.89±0.025
Average rainfall:			
Waupaca	1.15	4.06	3.65
Pine River	1.08	4.06	3.40
Standard deviation:			
Waupaca	.82	2.08	1.66
Pine River	.70	2.48	2.03

From these statistics the regression equations, expressing rainfalls at Waupaca in terms of rainfall at Pine River, are:

In deviation from the mean:
- January — $y=1.10\ x$
- May — $y=.77\ x$
- August — $y=.73\ x$

In total rainfall:
- January — $Y=1.10\ X-.03$
- May — $Y=.77\ X-.93$
- August — $Y=.73\ X-1.17$

The effect of increasing distance between stations upon the correlation coefficient is shown by the following table of correlation with May rainfall at Waupaca:

	Pine River	Grand River Locks	Portage	Beloit
	X_1	X_2	X_3	X_4
Distance from Waupaca, miles	14	40	58	126
Correlation coefficient	0.92±0.018	0.76±0.05	0.73±0.55	0.40±0.10
Mean rainfall	4.06	4.24	3.93	3.63
Standard deviation	2.48	2.20	1.87	1.79

The regression equations, expressing Waupaca rainfall in terms of the rainfalls at each of these four stations, are:

(The variables are the deviations in inches from the mean)

Distance
- 14 miles — $y=0.77\ x_1$
- 40 miles — $y=.72\ x_2$
- 58 miles — $y=.81\ x_3$
- 126 miles — $y=.46\ x_4$

(The variables are the monthly rainfalls in inches)

- 14 miles — $Y=0.77\ X_1+.93$
- 40 miles — $Y=.72\ X_2+1.01$
- 58 miles — $Y=.81\ X_3+.88$
- 126 miles — $Y=.46\ X_4+2.37$

The decrease of the correlation coefficient per mile amounts to 0.005 or 0.006.

Calculation of regression equations for two or more control stations is more complicated, but numerical examples that can be followed by any novice are given in the books referred to at the end of this article (6, p. 145), (4, p. 205), (2, p. 136–138). The labor is greatly reduced by the use of Miner's Tables (5) or Kelley's Alignment Chart (4, back cover) and Chiò's method of evaluating determinants (7, p. 71.)

As examples of such regression equations I have calculated three involving the three control stations, Pine River (14 miles south of Waupaca), New London (18 miles east), and Stevens Point (26 miles northwest.) The following table contains the statistics on which these calculations were based:

Correlation coefficients of stations in heading, with stations at left.—Monthly rainfalls for May, **32** *years,* **1897–1928**

	Waupaca	Pine River	New London	Stevens Point
	Y	X_1	X_2	X_3
Pine River	0.92±0.018			
New London	.85± .033	0.89±0.025		
Stevens Point	.92± .018	.88± .027	0.88±0.027	
Mean rainfall	4.06	4.06	4.08	3.80
Standard deviation	2.08	2.48	2.10	1.95

Regression equations—

(1) In deviation from the means:

$$y=+0.57\ x_1-0.10\ x_2+0.50\ x_3$$
$$y=+.80\ x_1+.14\ x_2$$
$$y=+.52\ x_1+.46\ x_3$$

(2) In monthly rainfalls, inches:

$$Y=+0.48\ X_1-0.10\ X_2+0.48\ X_3+.70$$
$$Y=+.68\ X_1+.14\ X_2+.75$$
$$Y=+.44\ X_1+.49\ X_3+.42$$

It will be noted that the smaller correlation between New London and Waupaca than between New London and the other controls, although the latter are farther away, has a marked effect in diminishing the New London coefficient in these multiple regression equations.

The labor of these calculations of multiple regression equations does not increase in proportion, when a number of equations are derived for different stations, based on the same controls, because the same intermediate coefficients are used again and again in the different relations.

In closing, I wish to acknowledge the cheerful assistance of Junior Observer Alfred L. Lorenz, who calculated all of the total correlations for me.

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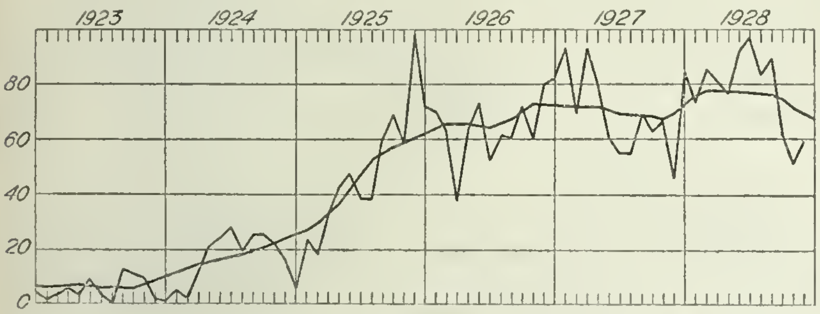
SMOOTHED MONTHLY MEANS OF SUN-SPOT RELATIVE NUMBERS, 1920-1929, INCLUSIVE [1]

[Furnished through the courtesy of Prof. W. Brunner, who made the observations and computations]

[Federal Astronomical Observatory, Zurich, Switzerland, January, 30, 1930]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1920	46.8	43.2	40.3	39.4	38.7	37.9	36.8	34.9	32.1	31.0	31.3	30.6	36.9
1921	31.0	31.7	31.1	29.0	27.3	26.5	25.3	24.4	25.5	25.8	24.3	22.5	27.0
1922	20.1	18.1	16.9	15.8	14.9	14.4	13.9	12.6	9.4	7.1	6.7	6.6	13.0
1923	6.4	5.9	6.0	6.6	6.9	6.4	5.6	5.6	5.7	5.8	6.8	8.1	6.3
1924	9.8	11.6	12.9	14.0	15.1	16.1	16.9	17.9	19.3	20.9	22.6	24.5	16.8
1925	25.9	27.1	29.3	32.6	35.9	40.9	47.2	51.8	55.6	57.7	58.9	60.9	43.7
1926	62.6	64.1	65.1	65.2	65.4	64.7	64.3	65.7	66.9	69.5	72.4	72.4	66.5
1927	72.0	71.8	71.7	71.7	71.6	70.5	69.1	68.4	68.3	68.4	67.7	69.0	70.0
1928	72.1	75.1	77.3	78.1	77.3	77.2	77.1	76.1	74.2	71.6	69.2	67.7	74.5
1929	66.2	64.3	61.3	58.6	59.6	63.0	64.8	64.0	62.8	61.1	60.6	57.5	62.0



SAN FRANCISCO FORECAST CENTER ADOPTS NEW BASE CHART

On January 29 the San Francisco district forecast center adopted a new base chart for use in charting weather reports received twice daily at that forecast center.

The new chart covers the Pacific Ocean from about the one hundred and eightieth meridian of west longitude eastward to and across the North American Continent to the Atlantic Ocean and in a north-south direction from about the thirty-fifth parallel of north latitude to the Arctic Ocean. The use of this base chart marks a great improvement in the facilities for charting weather reports from the Pacific and for the Canadian Northwest, including Alaska.—*A. J. H.*

TORNADO IN WARREN COUNTY, N. C., JANUARY 5, 1931 [2]

By CLARENCE E. SKILLMAN

[Weather Bureau, Raleigh, N. C.]

The storm, described as a large funnel-shaped cloud with a heavy roaring sound, struck first at about 4.35 p. m. on the farm of Mr. J. W. Bishop, 3 miles west of Wise in the northwest part of the county. It destroyed a tobacco barn and packhouse and moved half a mile northeast to where Jim Dunston, colored, lived in a log cabin in a grove of large oak trees. In a course about 100 yards wide it uprooted or twisted off practically every tree in the yard and destroyed completely the house and all outbuildings, killing Jim Dunston and three children outright, one son, 23 years old, dying next day in a hospital. A mile further on it dipped down to destroy a stable and two barns.

Three miles to the northeast, with occasional signs between, it struck in the neighborhood of the Warren County Training School for colored children. Here it struck Locust Grove colored church at the right side of its path, moving it 50 feet north and wrecking it. The colored Christian Church on the left of the path was blown away entirely, except for the floor and foundation. The roof is nowhere to be seen.

At the school there were several frame buildings grouped around a large frame 2-story building in the center. One building on the right, or southeast, side was not materially injured. The main building, directly in the path of the storm, evidently too substantial to be torn down, was moved north off its foundation and twisted beyond repair. Part of the roof on the south side was torn off. A girls' dormitory at the rear of the main building was wrecked, leaving only the floor and part of the partitions standing. About 20 girls were in this building at the time, most of them remaining there. Of those who ran out into the storm, one was struck and killed by a flying piece of timber and another, a teacher, sustained two broken ribs. None of those in the building were injured. A garage and implement shelter in the same line were demolished and the machinery damaged. A large poultry yard lying partly in the path of the storm was about half destroyed and 75 hens were taken up and carried several hundred yards and found dead. Another building at the left was only slightly injured. The top of a large pine standing at the right side of the path of the storm was broken off about 50 feet from the ground and carried 70 yards north and driven 10 feet into the corner of the main frame building.

In all, six people were killed and the property loss is estimated at $35,000.

PERIODIC OSCILLATIONS OF TEMPERATURE

By the late DR. C. EASTON

[Scheveningen, Netherlands]

[Meteorologische Zeitschrift, 1929, p. 171]

Relative to the interesting work of A. Wagner on the yearly oscillation of temperature in Europe in the last decades (Meteorologische Zeitschrift, 45 p. 364), I should like to make the following remarks:

Prof. A. Wagner finds that "the frequency * * * of mild winters in middle Europe in the last decades is such a striking phenomenon that it has been noticed not only by meteorologists, but also by everyone in the uninitiated class who experienced the severe winters at the close of the preceding century." The winters of 1917 (1916-17), 1922, and 1924, however, were certainly not mild; the first-named even ranks with severe winters and it would probably be better to take into consideration only the decade 1906-1916. Prof. A. Wagner compares the years 1886-1895 with the years 1911-1920, that is, the periods in which the temperature oscillation was greatest and least, respectively. As it appears to me, Prof. A. Wagner correctly concludes from his studies that one does not arrive at an explanation of this peculiarity through any secondary cause whatever; he believes that it is rather to be referred to a strengthening of the general circulation "now continuing for decades."

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[1] For summary of preceding years, see MONTHLY WEATHER REVIEW, August, 1920, vol. 48, p. 460.

[2] At 8 a. m. seventy-fifth meridian time January 5, 1931, a cyclonic storm was centered over southeastern Tennessee with central pressure down to 29.30 inches; in the next few hours it moved almost due northeast and its center must have passed on the left of Warren County at a probable distance of 50 to 75 miles. Tornadoes in January, although not unknown, are unusual.—*Editor.*

Recent epochs of maximum and minimum: Minimum, 1913.6, 1923.6; maximum, 1917.6, and probably about the middle of 1928.

It is very worthy of note that diminished yearly amplitude of temperature in Europe, as Prof. A. Wagner determines it for the next to the last decade, is manifest at intervals of 89 years in the historic data on winter weather. With diminished yearly oscillation there is associated a decided decrease in the frequency of very severe winters and, often, a high frequency of mild winters.

The last-named phenomenon was very evident in the next to the last decade; the winters of 1910, 1911, 1912(?), 1913(?), 1914, 1915, and 1916(?) showed a mean temperature in excess of the normal, that is, at least for western Europe.[1] This feature is so decided that in Petermann's Mitteilungen (1905, Heft 8) I ventured to predict that "there appears certainly warranted the inference of a period of extraordinarily few cold winters, at whose beginning we probably find ourselves at this time (1905)."

That earlier investigation, which was based on historical data relative to severe winters in western and middle Europe—mainly in the Alpine region and its vicinity [2]—collected by Wilhelm Köppen, drew attention to the presence of one or more rather long periods that were to be considered as multiple lengths of the well-known sun-spot period of approximately 11 years and that came to light both in the activity of the sun and in the oscillations of winter temperature in Europe; an 89-year period (8 by 11⅛ years) had been pointed out most plainly, especially in a very rare occurrence of severe winters toward the end of this long period.[3]

The historical material was much improved by myself through the addition of data on mild winters and by the limitation of the lines of argument to the climatic province of western Europe. (See, among other references, Peterm. Mitt., LXIII, 1917 and, especially, Les Hivers Dans l'Europe Occidentale; Etude Statistique et Historique Sur Leur Température. Tableaux Comparatifs, Notices Historiques, et Bibliographie. Leyden. E. J. Brill. 1928.) From my last compilation I take the following Table 1. In it the period 1205–1916 is divided into eight 89-year periods, and each period is subdivided into divisions of 22, 23, 22, and 22 years; here only the last two parts are cited (C: 1250–1271, and D: 1272–1293, etc.). The number of very severe, severe, and cold winters is given for each subdivision (above), and the number of moderate and mild winters (below). For example, we find for 1272–1293 winters noted as follows: Very severe, 0; severe, 3; cold, 3; moderate, 0; and mild, 2.[4]

In this it is to be borne in mind (1) that the data relative to mild winters are always very indefinite and very often unreliable; and (2) that the period is certainly somewhat variable and therefore the rises and falls do not fit exactly into the mathematical limits here given; thus, for example, the winter of 1895 (1894–1895) belongs without doubt in the preceding subdivision C; for the present free choice is to be avoided only by a strict mathematical division.

TABLE 1.—*Frequency of cold and mild winters in 22-year periods*

C		D	
1250–1271	0, 1, 5 / 0, 4	1272–1293	0, 3, 3 / 0, 2
1339–1360	0, 2, 5 / 0, 1	1361–1382	1, 3, 2 / 3, 0
1428–1449	1, 2, 1 / 0, 3	1450–1471	0, 3, 2 / 0, 4
1517–1538	0, 0, 4 / 2, 5	1539–1560	0, 3, 2 / 0, 2
1606–1627	2, 1, 4 / 2, 3	1628–1649	0, 0, 5 / 0, 3
1695–1716	1, 2, 3 / 4, 5	1717–1738	0, 1, 3 / 1, 1
1784–1805	3, 1, 3 / 3, 4	1806–1827	0, 2, 4 / 2, 3
1873–1894	2, 1, 4 / 0, 4	1895–1916	0, 1, 2 / 1, 6

We see that in the last four, most authentic, periods (since 1606) a marked excess of very cold winters is constant in C. Taken together these last four 89-year periods show the following frequency of cold and mild winters (totals in parentheses):

In Table 2 there comes to view still more plainly the marked temperature oscillation in C and the moderate number of cold and very cold winters in D. (D gives the summation of the periods 1628–1649, 1717–1738, 1806–1827, and 1895–1916.)

It is, however, very evident that the simple summation of very cold and very mild winters without regard to the plus or minus departure must give a good picture of the greater or lesser temperature oscillation. We find for all eight periods since 1205:

TABLE 2.—*Frequency of cold and mild winters in four 89-year periods since 1561*

Subdivision A	5, 10, 11 (26) / 4, 10 (14)	Subdivision C	8, 5, 14 (27) / 9, 16 (25)
Subdivision B	1, 9, 11 (21) / 2, 19 (21)	Subdivision D	0, 4, 14 (18) / 4, 13 (17)

TABLE 3.—*Total number of winters that were very cold or very mild*

Subdivision	1205–1916	1561–1916
A	43	24
B	31	30
C	39	30
D	25	8

For convenience, Table 4 in the original text has been combined with Table 3.

The great amplitude in C and the moderate amplitude in D comes to view very plainly, especially in the best authenticated data (period 1561–1916).

It is also possible to determine on an absolute scale, and with rather good approximation, the intensity of the temperature oscillation in C and D by means of "tem-

[1] For the climatic region of western Europe I found the temperature coefficients 65, 57, 74, 77, 55, 65, 74 (normal=50). Details in my work, Les Hivers Dans l'Europe Occidentales. Leyden, 1928, p. 208.

[2] Wl. Köppen. Über merkwürdige Perioden der Witterung usw., Zeitschr. d. Österreich. Ges. f. Meteorol., Bd. XVI. 1881. After my work of the year 1917 was published Professor Köppen discovered an 89-year period in his material. Compare Ann. d. Hydr. u. marit. Meteorol., XXV, 11, 1917 and Meteorol. Zeitschr. XXXV, 3, 4.

[3] C. Easton. Zur Periodizität der solaren und klimatischen Schwankungen, Peterm. Mitt. 1905, Heft 8. Compare Versl. Kon. Akad. v. Wetensch. Amsterdam, Nov. 26, 1904, June 24, 1905.

[4] It is evident that the older data are less complete than the later. In addition the terms "severe" and "mild" are here determined scientifically and do not always agree with the popular understanding. For the elaboration of the historical data see Les Hivers, introduction and, especially, pp. 166 and 200.

perature coefficients" obtained by critical comparison of historic and modern data. (See Les Hivers, p. 10 ff.) The departures of the coefficients from the normal of 50 (as given on p. 200 of the work mentioned) are found totaled in Table 4.[1]

Relative to the last result, 247 and 203, see remark on the winter of 1895.

TABLE 4.—*Totals of the departures of the temperature coefficients*

C		D	
1606–1627	306	1628–1649	138
1695–1716	388	1717–1738	135
1784–1805	336	1806–1827	222
1873–1894	247	1895–1916	203

The above table is numbered 5 in the original text.

These statistical data appear to indicate the correctness of the conclusion that the very remarkable phenomenon pointed out by Prof. A. Wagner is to be referred to a long-period oscillation coming to light for centuries in the historical data on winter temperatures. It was shown at an earlier date[2] that this 89-year periodicity agrees with—and is thus caused by—an oscillation in solar activity, both in the changing size of the spotted part of the sun's sufrace and also in the variable duration of the period of time between a minimum and the following maximum; the agreement becomes apparent also from the coincidence of an unusual cold wave at the close of the eighteenth century with an accelerated and intensified sunspot activity[3] at the same time. In conclusion I should like to add that I consider this 89-year periodicity not as a single period, but as a resonance or interference phenomenon at the coincidence of probably numerous independent periods, of which, however, no individual one has any considerable amplitude.

It would be interesting to test whether the 89-year oscillation comes more plainly into view in middle Eurpoe (as here for western Europe) in my newly revised data (Les hivers).—*Translated by W. W. Reed.*

COMMENTS ON THE INFLUENCE OF VEGETATION ON STREAMFLOW

By FRANCIS E. COBB, President and State Forester

[North Dakota School of Forestry, Bottineau, N. Dak., February 7, 1931]

I am much interested in the article[4] by Harry B. Humphrey and B. C. Kadel in regard to the influence of trees on stream discharge.

A small stream, Oak Creek, flows along the border of our campus, originating in springs located about 4 or 5 miles in the foothills of the Turtle Mountains. This is an intermittent creek and it is very common for this stream to discontinue flowing during the summer. In dry springs it may not flow after June. Sometimes it continues as late as August and occasionally runs throughout the year. However, it is commonly noticed that in the summer when it does not flow it always begins flowing as far down as we are located in the fall after the leaves have fallen from the trees. Sometimes it starts to flow even earlier than this. The article in question would lead me to believe that the growth of trees, which is quite heavy along its entire course to where we are located, have a great deal to do with the discontinuance of the flow during their growing period. It has often been wondered why after a dry summer it should begin in the fall even before the freezing of the ground, and this is apparently an explanation.

An article also in this same issue in regard to the passing of the mirage from the Weather Bureau at Dodge City, Kans., is also of interest.

We are a cooperative observer of the Weather Bureau at Bismarck and are naturally interested in all phenomena relative to weather conditions. Southeast of this town on clear, warm days during the entire summer a mirage lies, giving the appearance of a very large lake with tall trees on the banks and looks as though the farm houses in that section were entirely flooded, except for their upper stories This entire territory is in crop and apparently no difference appears whether the crop is growing or harvested.
I merely note this as a matter of interest inasmuch as here it does not depend on whether the prairie is bare or in crop.

[1] This is Table 5 in the original text.
[2] C. Easton. Peterm. Mitt. 1905 and Proceedings Kon. Akad. v. Wetensch. te Amsterdam, 4/5, 5/6, Bd. VII, VIII.
[3] Compare *Astronom. Mitt.*, R. Wolf and A. Wolfer. Zurich. A sunspot curve for 1745–1875 by Wilh. Myer is published in Das Weltgebäude, 1898, p. 295.
[4] See MONTHLY WEATHER REVIEW, October, 1930, vol. 58, p. 397, ff.

ARCTIC WEATHER STATIONS

By C. F. TALMAN

Just as, in the Southern Hemisphere, an outpost for weather observations maintained by the Argentine Government at Laurie Island, in the subantarctic South Orkneys, is operated by a small party who spend a year in complete isolation—being then replaced by another party—so in the far north the Russian Government has a number of weather stations whose staffs are relieved annually. The most northerly is the one established in Franz Josef Land in 1929. These arctic stations, like the one at Laurie Island, are equipped with radio.

Last summer the ice breaker *Sedov* visited the station in Franz Josef Land, where the seven members of the staff were found in good health. They were replaced by a new staff of 10 men and 1 woman. The latter, the wife of the director, is to conduct biological investigations.

From Franz Josef Land the *Sedov* proceeded through ice fields to the archipelago north of the Taimyr Peninsula formerly known as Emperor Nicholas II Land but now called Severnaya Zemlya (Northern Land). Some previously unknown islands were discovered, including a group of small ones to which the name Kamenev Islands was given, and in one of these a new station was established, in latitude 79° 24′ north and longitude 91° 3′ east. Four men were left here, with provisions for three years.—*Why the Weather—Scientific Service* (*Inc.*).

LIGHTNING FROM A CLEAR SKY, JANUARY 20, 1931

By FRED MYERS

[Weather Bureau, Tatoosh Island, January 20, 1931]

At 4:17 a. m. a flash of lightning was observed overhead and slightly toward the north. The sky was clear with about 2 strato-cumulus clouds along the horizon from the southwest to the northwest. There were six or eight flashes from 4:17 a. m. to 4:32 a. m., no more being observed until 5:15 a. m. when a single flash occurred in about the same location as the others.

Light rain had been falling during the night, ending about 2:45 a. m., the sky clearing by 4 a. m., the stars were shining brightly and the clouds could be seen distinctly in the west. The lightning appeared to flash across the sky and not to the ground. No thunder followed the flashes. This is the first time lightning has occurred from a clear sky at this station as far as can be determined.

The wind was from the south about 23 miles per hour, the temperature 48°; the barometer 30.16 and humidity 92 per cent at 4:45 a. m. (120 meridian time).

While only a few flashes were observed, the "howler"[1] on the composite telephone was very noisy, sounding like static on a radio. This was probably due to lightning near Port Angeles. The Navy radio operator said that he had not noticed any lightning, but that the static had been bad all night.

[1] The composite phones "ring" by a buzzer arrangement which is heard through the "howler." This is nothing more than a receiver with a small horn to amplify the sound. It is connected to the line so that any noise on the line is heard through the "howler."

CLIMATOLOGICAL SUMMARY FOR CHILE NOVEMBER AND DECEMBER, 1930

By J. BUSTOS NAVARRETE

[Observatorio del Salto, Santiago, Chile]

November.—Atmospheric circulation was less active than in October. Important depressions crossed the extreme southern region in the following periods: 8th-10th, 18th-20th, 24th-26th, and 27th-29th. Anticyclones, all moving from southern Chile toward Argentina, were charted from 4th to 7th, 12th to 17th, and 24th to 26th.

December.—Despite the advance of the season the atmospheric circulation continued active, ending in a severe storm in the south near the summer solstice. Well defined depressions crossed the southern region during the periods 2d-3d, 10th-13th, and 18th-21st. Anticyclones showed but little intensity, the one with greatest development being that of the 22d-26th moving from southern Chile toward northeastern Argentina and Brazil.—*Translated by W. W. Reed.*

FRANKLIN G. TINGLEY, 1871-1931

Franklin Ginn Tingley was born October 8, 1871, at Marion, Ind., and died at Hyattsville, Md., January 26, 1931. He was educated at the public schools of his native town and at Purdue University, from which he was graduated with the degree of bachelor of civil engineering. He was appointed to the Weather Bureau July 16, 1898, and was one of the pioneer observers of the West Indian weather service organized by the bureau during the Spanish-American War primarily for the protection of the American fleet in Caribbean waters. After a brief period of instruction at Washington, he served at Kingston, Jamaica, as assistant to W. B. Stockman, who was in charge of the West Indian service. When the headquarters of the service were moved from Kingston to Habana in January, 1899, Tingley remained at Kingston in charge of the station. In June, 1899, he was transferred to Habana. In August, 1899, on account of illness, he was recalled to the United States, and served successively at the Atlanta, Wilmington, and Jacksonville stations of the Weather Bureau. In November, 1901, he was assigned to the central office at Washington, where for many years he was connected with the administrative branch of the bureau.

Meanwhile he became deeply interested in certain scientific problems, especially as bearing upon the question of extending the period of weather forecasts. In June, 1916, he was assigned to the climatological division to pursue his studies of forecasting and also to take charge of the marine section of that division. On April 1, 1920, the marine section was made a separate division, and Tingley became its chief. He served in this capacity up to the time of his death. The marine work of the bureau was greatly enlarged under his capable direction, including, among its more recent developments, a comprehensive revision of wind-roses for the Pilot Charts and the beginnings of a far-reaching study of surface-water temperatures.

Modest, gentle, and unselfish to an extraordinary degree, Tingley won the affection of everybody with whom he came in contact. His death was a grievous personal loss to his late colleagues and associates.—*C. F. T.*

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Ashbel, Dob.
Die Niederschlagsverhältnisse im südlichen Libanon, in Palästina und im nördlichen Sinai. Berlin. 1930. 79 p. figs. 23 cm. (Inaug.-Dissert. Friedrich-Wilhelms-Univ. Berlin.)

Clyde, George D.
Establishing snow courses and making snow surveys. Logan. n. d. 16 p. illus. 23 cm. (Utah agric. exper. sta. Circ. 91. Dec. 1930.)

Gallé, P. H.
Klimatologie van den Indischen Oceaan. V. Neerslag. VI. Frequentie van luchtdrukkingen en stormachtige winden. VII. Tropische cyclonen. Amsterdam. n. d. 31 p. illus. plate (fold.). 24 cm. (K. Ned. met. inst. no. 102. Med. en verh. 29c.)

Harmer, Paul M.
Prevention of wind injury to crops on muck land. East Lansing. n. d. 8 p. illus. 23½ cm. (Agric. exper. sta. Mich. state coll. Soils sec. Circ. bull. no. 103. March, 1927.)

Hölcke, Theodor.
Der Einfluss der Höhenlage auf die Niederschläge in Thüringen. Weimar. (1930. 47 p. figs. map (fold.). 21 cm. (Mitt. der Thür. Landeswett. Heft 2.)

International commission for the study of clouds.
International atlas of clouds and of states of the sky. Abridged edition for the use of observers. Paris. 1930. ii, 41 p. 41 plates. 32 cm.

International meteorological organisation.
1r rapport de la Commission internationale de l'année polaire 1932-1933. Compte-rendu des travaux de la commission pendant sa première année de travail. Procès-verbaux des séances de la réunion à Leningrad août 1930. Leyde. 1930. iv, 152 p. figs. plates. 24½ cm. (Sec. de l'Organ. mét. internat. No. 6.)

Kochergin, V.
Atmosfernye osadki Zakavkaz'ia. Tiflis. 1928. xxv, 347 p. 25 cm. [Rainfall in Transcaucasia.] (Transcaucasian water admin. Div. sci. invest. no. 51.)

McEwen, George F.
Results of evaporation studies conducted at the Scripps institution of oceanography and the California institute of technology. Berkeley. 1930. p. 401-415. 27½ cm. (Bull. Scripps inst. ocean., Tech. ser., v. 2, no. 11.)

Pettersson, Vilhelm I., & Pettersson, Otto.
Cartes synoptiques trimestrielles donnant la température et la salinité de l'eau de surface de l'océan Atlantique Nord. n. p. n. d. [3 p.] fig. plates (fold.) 35 cm.

Richard, W.
Wetter und Verkehrswesen. v. p. figs. 30 cm. (Die Reichsbahn. nr. 37-39. Jahrg. 1929. 11, 18, 25 Sept.)

Welter, L.
Note sur l'organisation de la protection météorologique de la navigation aérienne en Afrique Occidentale Française. [Paris. 1930.] 8 p. figs. 25½ cm. (Bull. du comm d'études hist. et scient. de l'Afrique Occident. Franç. Année 1930. T. 13.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS, JANUARY, 1931

By HERBERT H. KIMBALL

At Washington, D. C., Madison, Wis., and Lincoln, Nebr., the Weather Bureau has installed Marvin pyrheliometers with which, when the sky is free from clouds, measurements of the intensity of direct solar radiation are obtained.

At Washington the measurements are made on the campus of the American University, about 5½ miles northwest of the United States Capitol, 3 miles northwest of the Central Office of the Weather Bureau, and 1½ miles northwest of the United States Naval Observatory. There are no manufacturing establishments within a radius of about 3 miles, but the suburb about the university is rapidly building up, principally with detached houses. The pyrheliometer is exposed on a shelf outside a window, in the morning on the southeast side of the building and in the afternoon on the southwest side. At times, with southeast or east winds, city smoke is brought over the university. The pyrheliometer is at latitude 38° 56′ north, longitude 77° 05′ west, altitude 397 feet.

At Madison the pyrheliometer is installed in North Hall, University of Wisconsin, and exposed on a shelf outside a window facing east in the morning and west in the afternoon. North Hall is on a bluff in the upper campus, a short distance from the south shore of Lake Mendota. Most of the manufacturing plants are in the eastern part of the town, but railroad tracks and the heating plant of the university are to the Southwest. With a northwest wind the air is free from smoke, but with the wind from other directions considerable smoke is brought over the campus. The latitude of North Hall is 43° 05′ north, longitude 89° 23′ west, altitude 974 feet.

At Lincoln the pyrheliometer is exposed in the experiment station building, on the farm campus, State University Farm. It is 2½ miles northeast of the center of the business section of the city, but there is some smoke from buildings on the farm campus and from railroads and shops not far to the north. Under certain conditions the city smoke cloud covers the farm campus, but with a west to northwest wind the atmosphere is very clear. The latitude of the farm campus is 40° 50′ north, longitude 96° 41′ west, altitude of pyrheliometer above sea level 1,225 feet.

When observing, the pyrheliometer is exposed on a shelf outside a south dormer window.

Continuous records of the intensity of the solar radiation received on a horizontal surface, including that received diffusely from the sky, are obtained by the Weather Bureau at Madison, Wis., and Lincoln, Nebr., by means of Callendar pyrheliometers. The registers are installed in the rooms with the auxiliary apparatus used with the Marvin pyrheliometers, and the geographical coordinates for the two stations are as already given. The Callendar pyrheliometers are exposed on the roofs of the buildings occupied—at Madison at an elevation of 1,009 feet and at Lincoln of 1,250 feet above sea level. Both these pyrheliometers have practically unobstructed exposure to the sky down to the horizon in every direction.

A summary of continuous records obtained by means of a Callendar recording pyrheliometers is received each month for publication in the MONTHLY WEATHER REVIEW from Mr. O. J. Sieplein, director of the Belle Isle Observatory, University of Miami, Miami, Fla., at latitude 25° 41′ north, longitude 80° 12′ west, altitude but a few feet above sea level. A similar summary is received from the Scripps Institution of Oceanography, La Jolla, Calif., latitude 32° 50′ north, longitude 117° 15′ west, altitude 85 feet above sea level; but at this latter station a Weather Bureau thermoelectric pyrheliometer recording on an Engelhard microammeter is employed.

Records are also obtained at the American University, D. C., the Weather Bureau stations at Chicago, Ill., New York, N. Y., Pittsburgh, Pa., and Fresno, Calif., at Twin Falls, Idaho, through cooperation with the Bureau of Entomology, Department of Agriculture, and at Gainesville, Fla., through cooperation with the department of physics, University of Florida. Fresno and Gainesville employ Moll thermoelectric pyrheliometers, the former recording on an Engelhard, the latter on a Richard microammeter. The other stations employ the Weather Bureau type of thermoelectric pyrheliometers and Engelhard recording microammeters. In New York City the radiation apparatus is exposed at the New York Meteorological Observatory, Central Park, and in Chicago on the tower of Rosenwald Hall, on the University of Chicago campus.

Coordinates of these stations are as follows:

Station	Latitude	Longitude	Altitude
	° ′	° ′	*Feet*
Chicago, Ill	41 47 N.	87 35 W.	688
New York City	40 46 N.	73 58 W.	156
Pittsburgh	42 26 N.	80 00 W.	1114
Fresno	36 43 N.	119 49 W.	350
Twin Falls	42 29 N.	114 25 W.	4300
Gainesville	29 39 N.	82 21 W.	233

At Chicago the pyrheliometer is exposed to the south of the tower on which the wind instruments are exposed and which shades it from a part of the north sky. The same is true of the exposure in New York to a lesser extent and also at Fresno. At Washington the roof of the Chemical Laboratory, about 300 feet to the north, cuts off a small section of the sky near the horizon.

All pyrheliometers from which records are summarized in Tables 1 and 2 have been standardized by comparison with Marvin No. 3, except the Callendar instrument at Miami, which has a standardization certificate furnished by the English manufacturer. Quite probably this certificate gives radiation intensities in the Ångström scale, but I have been unable to obtain definite information on this point. Marvin No. 3 is checked with Smithsonian substandards from time to time through Smithsonian No. 1, which is owned by the Weather Bureau.

Table 1 shows that solar radiation intensities averaged above the normal intensity for January at Washington, D. C., and slightly below normal at Madison, Wis., and Lincoln, Nebr.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at all stations except Madison, for which there was a pronounced deficiency.

Skylight polarization measurements were obtained at Washington on five days and give a mean percentage of 56, with a maximum of 59 on the 2d and 13th. These are below the corresponding averages for Washington in January. No measurements were obtained at Madison during this month, as the ground was continuously covered with snow.

TABLE 1.—*Solor radiation intensities during January, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	1.0[1]	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 2	1.96	0.98	1.10	1.22	1.38			1.27	1.11	0.98	2.06
Jan. 7	2.16	0.66	0.78		1.16			1.09			2.16
Jan. 9	2.26		0.63	0.78	0.98			0.90			2.87
Jan. 13	4.75				1.20						2.62
Jan. 15	1.24		1.10	1.21	1.31			1.11	0.98	0.75	1.52
Jan. 16	1.78		0.86	0.98							2.06
Jan. 17	3.45			1.07	1.26			1.08	0.94	0.82	3.45
Jan. 20	2.87		0.89					1.14	0.99	0.81	2.62
Jan. 22	1.12				1.06						1.52
Jan. 28	4.95			0.84	1.03		1.01				4.17
Jan. 30	3.30				0.97						2.36
Means		(0.82)	0.89	1.02	1.15		(1.01)	1.10	1.00	0.84	
Departures		+0.09	+0.04	+0.01	−0.08		−0.22	+0.06	+0.12	+0.04	

Madison, Wis.

Jan. 3	2.26	0.76	1.00	1.09				1.14			3.63
Jan. 9	3.15	0.97	1.07	1.17				1.30			2.87
Jan. 16	2.87	0.76	0.90	1.06				1.10			3.45
Jan. 22	1.78							0.96			1.78
Jan. 26	2.36	0.94	1.11	1.17	1.40						2.87
Means		0.88	1.02	1.12	(1.40)			1.12			
Departures		−0.07	−0.03	−0.08	+0.04			−0.08			

Lincoln, Nebr.

Jan. 2	3.45	0.93	0.99	1.12							3.63
Jan. 4	3.00							1.21	1.07	0.97	3.63
Jan. 5	2.49	1.05	1.17								3.00
Jan. 14	1.02	1.04	1.08								1.07
Jan. 15	1.88							1.11	0.98	0.86	3.00
Jan. 16	2.36							1.02	0.86	0.80	3.81
Jan. 21	2.26		1.07	1.17				1.14			3.63
Jan. 26	3.30	1.04	1.13	1.21	1.40						3.63
Jan. 28	3.30				1.36			1.14	1.04	0.93	4.57
Jan. 29	3.63		0.82	1.15	1.30						4.37
Jan. 31	3.45		1.02	1.20	1.39		1.38	1.22	1.11	1.00	3.15
Means		1.02	1.04	1.17	1.36		(1.38)	1.14	1.01	0.91	
Departures		+0.08	−0.01	−0.01	−0.01		−0.03	−0.03	−0.03	−0.01	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning—	Average daily totals										
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	175	105	189	68	113	183	115	276	128	220	262
Jan. 8	168	119	232	98	137	152	93	239	211	237	233
Jan. 15	196	149	202	95	146	220	130	216	227	279	145
Jan. 22	172	162	235	121	138	224	166	296	212	261	223
	Departures from weekly normals										
Jan. 1	+21	−29	+4	−12	+9	+2	+26	−2	−15	−13	----
Jan. 8	+14	−25	+40	+15	+34	−40	+1	−4	+45	+10	----
Jan. 15	+37	−12	+1	−2	+34	+18	+18	−16	+35	+48	----
Jan. 22	−7	−26	+12	+8	−2	+27	+42	+26	−21	+21	----
Accumulated departures on Jan. 28	+455	−644	+399	+63	+525	+49	+609	+28	+308	+462	----

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	*h*	*m*	°	°	°			
Jan. 1 (Naval Observatory)	11	14	No spots					
Jan. 2 (Naval Observatory)	11	18	No spots					
Jan. 3 (Naval Observatory)	11	49	No spots					
Jan. 4 (Naval Observatory)	11	4	−78.0	237.6	−18.0		62	62
Jan. 5 (Mount Wilson)	14	0	−65.0	235.8	−19.0		122	
			−51.0	249.8	−12.0	12		134
Jan. 6 (Mount Wilson)	13	15	−49.0	239.1	−19.0		129	
			−48.0	240.1	−10.0		5	134
Jan. 7 (Naval Observatory)	11	41	−35.0	240.8	−18.5		108	108
Jan. 8 (Naval Observatory)	11	41	−20.5	242.1	−19.5		77	77
Jan. 9 (Naval Observatory)	12	3	−9.0	240.2	−18.5		123	123
Jan. 10 (Naval Observatory)	11	49	+6.0	242.2	−19.0		62	62
Jan. 11 (Naval Observatory)	11	41	+18.0	241.1	−19.0		46	46
Jan. 12 (Mount Wilson)	14	10	+4.0	212.5	+8.0	20		
			+34.0	242.5	−19.0	32		52
Jan. 13 (Naval Observatory)	12	12	+19.0	215.5	+9.0		62	
			+45.0	241.5	−19.5	31		93
Jan. 14 (Naval Observatory)	13	12	+29.0	211.7	+7.0		123	
			+33.5	216.2	+7.0	46		169
Jan. 15 (Naval Observatory)	11	43	+40.0	210.4	+8.0		170	170
Jan. 16 (Naval Observatory)	14	14	+55.0	210.8	+8.5		463	463
Jan. 17 (Naval Observatory)	11	37	+67.5	211.6	+8.5		355	355
Jan. 18 (Mount Wilson)	13	25	−22.0	107.9	+5.0		71	
			+80.0	209.9	+8.0		337	408
Jau. 19 (Mouut Wilson)	14	10	−70.0	46.4	+2.0	4		
			−5.0	111.4	+5.0		84	88
Jan. 20 (Naval Observatory)	11	54	−55.0	49.5	+2.0	19		
			+8.5	113.0	+6.5		123	142
Jan. 21 (Naval Observatory)	11	42	+20.0	111.4	+5.0		93	93
Jan. 22 (Naval Observatory)	13	18	+35.0	112.4	+6.5		154	154
Jau. 23 (Naval Observatory)	12	30	+9.0	74.6	+8.0	3		
			+48.0	113.6	+3.0		154	157
Jan. 24 (Naval Observatory)	12	43	+59.0	110.3	+5.0		139	139
Jan. 26 (Perkins Observatory)			No spots					
Jan. 27 (Naval Observatory)	11	19	No spots					
Jan. 28 (Naval Observatory)	11	21	+48.0	47.4	+3.0		31	31
Jan. 29 (Naval Observatory)	13	52	No spots					
Jan. 30 (Naval Observatory)	12	13	No spots					
Jan. 31 (Naval Observatory)	11	29	+10.0	329.9	+3.5	9		9
Mean daily area for January								109

AEROLOGICAL OBSERVATIONS

By L. T. Samuels

Free-air temperatures during January were exceptionally high at Ellendale, with the departures decreasing with increase in altitude. (See Table 1.) Positive temperature departures occurred also at Royal Center and in the lower levels at Broken Arrow. Elsewhere the departures were negative.

Free-air relative humidity departures were variable and of small magnitude at all stations. Those for vapor pressure were in agreement with the temperature departures.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1931*

TEMPERATURE (° C.)

Altitude Meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	3.8	+0.6	3.8	−1.6	−5.0	+6.1	6.5	−1.5	−0.8	+3.5
500	4.8	+2.0	5.0	−0.3	−4.8	+6.2	7.0	−0.5	−1.9	+3.5
1,000	4.0	+1.3	4.0	−0.5	−1.7	+7.1	5.7	−1.6	−2.9	+2.4
1,500	2.2	−0.2	2.7	−0.3	−3.3	+4.8	4.3	−2.1	−3.9	+1.9
2,000	0.6	−0.4	0.9	−0.2	−5.9	+3.7	1.9	−2.8	−5.2	+1.6
2,500	−1.7	−0.5	−1.4	−0.4	−8.4	+3.4	0.0	−2.6	−6.9	+1.8
3,000	−4.4	−0.7	−4.2	−1.0	−10.8	+3.6	−2.5	−2.8	−9.2	+1.8
4,000	−11.4	−2.2	−10.5	−2.1	−16.9	+2.9			−15.3	−0.2
5,000			−15.8	−1.8					−22.1	

RELATIVE HUMIDITY (%)

Altitude Meters m. s. l.	Broken Arrow, Okla. Mean	Departure from normal	Due West, S. C. Mean	Departure from normal	Ellendale, N. Dak. Mean	Departure from normal	Groesbeck, Tex. Mean	Departure from normal	Royal Center, Ind. Mean	Departure from normal
Surface	75	+5	77	+7	80	−1	78	+1	80	+1
500	64	0	65	+3	78	−1	61	−9	79	+5
1,000	56	+1	58	+1	63	−3	52	−9	70	+7
1,500	51	+5	52	−1	60	+1	47	−6	61	+5
2,000	41	0	48	−1	60	+2	48	0	53	+2
2,500	37	−3	45	0	58	0	47	+2	49	−3
3,000	37	−3	44	+2	55	−3	43	+2	49	−4
4,000	34	−8	49	+8	55	+1			50	−4
5,000			75	+25					54	

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during January, 1931*—Continued

VAPOR PRESSURE (*mb.*)

Altitude Meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.08	+0.40	6.17	−0.55	3.51	+1.11	7.83	−1.03	4.75	+0.94
500	5.63	+0.57	5.61	−0.44	3.47	+1.12	6.46	−1.34	4.30	+0.99
1,000	4.64	+0.44	4.61	−0.67	3.36	+1.21	5.06	−1.44	3.38	+0.59
1,500	3.54	+0.17	3.73	−0.58	2.84	+0.87	3.94	−1.29	2.57	+0.24
2,000	2.45	−0.29	2.95	−0.52	2.33	+0.63	3.34	−0.84	2.02	+0.10
2,500	1.91	−0.39	2.39	−0.30	1.77	+0.38	2.83	−0.54	1.58	−0.07
3,000	1.52	−0.43	2.00	−0.11	1.26	+0.18	2.26	−0.40	1.23	−0.21
4,060	1.12	−0.29	1.42	+0.02	0.55	−0.03			0.89	−0.12
5,000			1.31	+0.18					0.67	

TABLE 2.—*Free-air data obtained at naval air stations during January, 1931*

Altitude (meters) m. s. l.	Temperature (° C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	3.7	7.4	13.4	−1.4	73	80	60	73
500	3.5	7.7	13.5	−0.6	64	72	55	61
1,000	1.3	6.2	11.9	−1.6	58	64	45	56
2,000	−3.7	3.9	6.6	−5.3	52	51	40	49
3,000	−7.3	−1.0	0.6	−8.1	46	45	32	34

In Table 3 are shown the resultant free-air winds for a representative group of stations. The light resultant velocities and variable directions at the upper levels in the extreme western part of the country are conspicuous as compared with the more uniform northwesterly directions in the central and eastern sections.

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observatoins made near 7 a. m. (E. S. T.) during January, 1931*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 55 W	0.5	N 7 E	0.3	S 7 W	0.8	N 75 W	5.5	S 83 W	1.5	N 71 W	2.5
500	S 77 W	2.8	S	2.6	S 86 W	3.3			N 74 W	4.9	N 78 W	3.8
1,000	N 78 W	5.4	S 33 W	2.0	N 80 W	6.8			N 73 W	5.2	N 55 W	8.9
1,500	N 77 W	6.3	S 58 W	1.9	N 69 W	9.7			N 73 W	7.6	N 56 W	10.6
2,000	N 63 W	7.4	N 76 W	3.6	N 60 W	13.1	N 77 W	8.3	N 88 W	8.8	N 51 W	12.1
2,500	N 54 W	9.3	S 77 W	7.4	N 74 W	14.7	N 68 W	13.4	N 67 W	9.1	N 50 W	13.3
3,000	N 53 W	7.7	S 75 W	7.4			N 57 W	12.5	N 77 W	6.6	N 52 W	12.2
4,000			S 85 W	9.6			N 55 W	11.0				
5,000			S 78 W	11.1			N 71 W	7.6				

Altitude (meters) m. s. l.	Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 m.)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 50 W	0.7	S 62 W	3.7	N 50 W	1.4	N 39 E	2.9	N 35 E	2.2	S 17 W	0.5
500	N 78 W	2.4			N 44 W	2.6	N 61 E	5.4	N 57 E	1.3	S 27 E	1.3
1,000	N 71 W	4.6	S 71 W	9.1	S 88 W	3.5	N 65 E	3.2	N 74 E	0.9	S 30 E	3.8
1,500	N 65 W	4.4	N 85 W	10.7	N 83 W	5.8	S 28 W	0.4	N 85 E	1.6	S 7 W	4.0
2,000	N 57 W	4.1	N 75 W	12.4	N 62 W	6.4	S 55 W	1.7	N 81 E	2.5	S 36 W	5.2
2,500	N 74 W	5.9	N 69 W	10.1	N 66 W	8.7	N 89 W	3.7	N 66 E	2.2	S 47 W	5.6
3,000	N 80 W	6.2	N 68 W	11.2	N 72 W	10.8			S 68 W	1.2	S 84 W	2.8
4,000	S 80 W	5.5									S 50 W	1.7
5,000												

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during January, 1931*—Continued

Altitude (meters) m. s. l.	Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,294 meters)		San Francisco, Calif. (8 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Spokane, Wash. (606 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 68 W	0.9	S 81 W	2.4	N 19 E	0.9	W	0.9	S 71 E	3.7	S 63 W	2.5	S 40 E	0.7	S 77 E	0.8	N 31 E	0.5	S 46 E	1.5	S 15 E	0.8	N 53 W	1.4
500	N 79 W	4.6			N 5 W	4.1	N 70 W	3.8	S 84 E	4.2	S 87 W	7.1			N 33 E	2.0	N 66 W	1.6	S 8 W	7.0			N 67 W	7.5
1,000	N 69 W	6.1			N 29 W	4.1	N 61 W	8.5	N 82 E	3.5	N 78 W	7.7			N 30 E	1.6	N 57 W	6.3	S 18 W	8.3	S 19 W	3.5	N 67 W	9.8
1,500	N 88 W	7.1			N 53 W	4.5	N 67 W	10.3	N 80 E	2.1	N 87 W	12.4	S 16 E	1.4	N 47 W	0.8	N 48 W	9.2	S 33 W	7.7	S 51 W	7.5	N 73 W	11.5
2,000	N 83 W	7.1	N 57 E	1.9	N 69 W	4.2	N 67 W	11.7	S 73 E	1.1	N 82 W	13.4	S 11 W	3.1	N 35 W	1.7	N 53 W	12.6	S 36 W	7.1	S 65 W	8.7	N 77 W	10.3
2,500	N 85 W	10.3	N 71 E	3.2	N 70 W	3.7	N 69 W	13.0	S 16 W	0.5	N 66 W	13.6	S 41 W	2.1	N 41 W	1.9	N 54 W	14.1	S 76 W	6.9	S 66 W	10.0	S 84 W	8.9
3,000	N 87 W	11.7	N 53 E	1.5	N 61 W	3.6	N 60 W	14.8	N 69 W	0.8			N 79 W	3.0	N 30 W	1.6	N 57 W	16.0			S 68 W	9.2		
4,000			N 59 W	3.6			N 52 W	15.3	N 39 W	7.4			S 78 W	7.8	N 65 W	1.7								
5,000			N 49 W	5.5																				

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during January, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, meters m. s. l., reached during month	2,823	2,640	2,997	2,561	2,895
Maximum altitude, meters m. s. l., reached	4,032	5,123	4,518	3,938	6,209
Number of flights made	31	33	29	21	28
Number of days on which flights were made	28	29	29	21	28

In addition to the above, there were approximately 176 scheduled pilot balloon observations made daily at 60 weather bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The month of January was abnormally warm and dry. However, in the extreme southern portions of the country, the more northeastern States, and the central Plateau the temperature averaged below normal. Elsewhere the month was generally warm, especially in the area between the Great Lakes and Rocky Mountains, where the monthly means were from 12° to 19° above the average.

The precipitation for the month was heavy in much of Texas, and normal or above in the Gulf section including Florida, and in the south Pacific districts and parts of Washington. Elsewhere the falls were generally scanty, with large areas continuing remarkably dry. In practically all central valley sections, and generally in the Great Plains, much of the Rocky Mountain region, and the central Plateau less than half the normal was received.

TEMPERATURE

The eastern and south-central portions of the country were experiencing moderately cool weather at the beginning of January, and in the coast districts from the Carolinas to the Rio Grande, likewise in the southern Appalachians and the lower Mississippi Valley, the low temperatures prevailed without material interruption until about the 22d. Conditions varied more in the Northeast and from the Ohio Valley northward, but the first three weeks were mainly milder than normal in these sections, especially in the middle and western portions of the Lake region.

From the middle and upper Mississippi Valley westward over the Plains to the Rocky Mountains decidedly mild weather prevailed during the first three weeks, except for a brief cold period about the 12th to 14th. West of the divide there was usually warm weather in the Pacific States, but cold weather in a large part of the Plateau region.

The last 10 days of January were unseasonably warm in most districts, only a small area centering in northern Utah and a larger area covering nearly all of New York and New England, having colder weather than normal. Remarkably high temperatures for January were noted from the North Pacific States to Lake Superior and over the Plains and the central valleys. New high marks for January were noted at several stations during the last five days of the month.

The month resembled December just before it, being far warmer than normal in the north-central portion of the country and cooler than normal in the Southeast and in large portions of the Rio Grande Valley and the Plateau. Unlike December, January was warmer than normal in the Middle Atlantic States, the Ohio Valley, northern and central Texas, nearly all of Colorado, Nevada, and Idaho, and practically every part of the Pacific States. Only Utah and Florida sections averaged more than 2° colder than normal. Minnesota and the Dakotas averaged 13° to 15° warmer than normal, and over most North-central States this was the warmest January of record, or the warmest save 1880.

In California and Florida the highest temperatures came during the first week, but in almost every other State during the closing week. The lowest marks in the far West came during the opening decade, but from the Plains southeastward to the south Atlantic coast very near the middle of the month.

PRECIPITATION

The first eight days brought much precipitation in the Pacific States, and about the 11th there was considerable in Texas. The east Gulf and Atlantic regions received important amounts about the 5th, and substantially all their month's supply during the period from the 4th to the 18th. For almost all the country the last fortnight of January was without important precipitation.

The month was decidedly dry over the country as a whole. In this it resembled December just preceding, and, like December, there were moderate excesses in Florida and much of Texas. Unlike December, January brought more than normal precipitation to most of southern California and to Washington.

While the Gulf coast section had about as much rain as normal and the Lake region reported but a slight precipitation deficiency, yet most of the great area between the Rocky Mountain and Appalachian Divides had a marked deficiency, especially the middle and lower Ohio Valley, northern Arkansas, the Dakotas, and Minnesota. The middle and southern Plateau and the Middle Atlantic States likewise had considerable shortages.

As a result of the long-continued deficiency of precipitation, the major portions of the Mississippi and some other rivers were reported at the lowest stages ever known in midwinter.

Southwestern Texas, in marked contrast to a great part of the country, received more than three times the normal January rainfall, while in Florida, January, with about 120 per cent of normal, was the third successive month of more than normal rainfall.

SNOWFALL

There have been few Januarys with less snowfall, taking the country as a whole. The southern Middle Atlantic States, Ohio Valley, Minnesota and practically all the Plains had decidedly small amounts, compared with their average January quantities.

From eastern Iowa eastward and northeastward over the Lake region there was not so marked a deficiency; and New York, save the southeastern part, and almost all of New England had considerably more than normal snowfall. In New York no January since 1925 has brought so much snowfall as the present one, and the New England average amount for this month has been exceeded in January only three times within the last quarter century.

Most of the far West reported a considerable shortage of snowfall, compared with the expected quantity. The supply of stored snow in the higher portions is small, on the whole; it is usually least unsatisfactory near and for a moderate distance to westward of the Continental Divide, between the Canadian boundary and the central portions of Colorado and Utah.

The ground was bare to an extraordinary extent over the northern Plains and westward to the foothills of the Rockies, also in southern Minnesota and from Kansas and Missouri eastward over the Ohio Valley.

SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed in the region of the Great Lakes and upper Ohio Valley, southern Florida, the far Northwest and northern Pacific States, while in the western portion of the Great Plains much sunshiny weather prevailed, western North Dakota receiving about 70 per cent of the possible. Elsewhere about the normal amounts of sunshine were received. The relative humidity was generally above the normal in Texas and portions of the adjacent States, in much of the Great Basin and Plateau region, and portions of the Lake region and northern New England, while elsewhere it was generally near or below the normal. However, the departures from the normal were nowhere large.

SEVERE LOCAL STORMS, JANUARY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Uniontown, Pa., and vicinity.	5	Noon	3,520		$100,000	Severe wind	Many buildings unroofed, some completely wrecked; overhead wires torn down; plate glass broken; many minor injuries.	Official, U. S. Weather Bureau.
Caswell County, N. C. (4 miles north of Yanceyville).	5	4 p. m.	200–300		10,000	Tornado	Number of buildings demolished, others unroofed; 2 persons injured; path 10 miles long.	Do. News and Observer (Raleigh N. C.).
Warren County, N. C. (3 miles west of Wise).	5	4.35 p. m.	100–200	6	35,000	Do	Farm buildings, a training school, and 2 churches demolished; poultry killed; trees uprooted or twisted off; path 4 miles long.	Official, U. S. Weather Bureau.
Mecklenburg County, Va. (near Boydton).	5	5 p. m.	100	1	3,500	Do	House and other buildings blown down; path 2 miles long.	Do. Washington Post (D. C.).

RIVERS AND FLOODS

By RICHMOND T. ZOCH

Floods in January, 1931, were local and of very minor importance. They occurred in the Santee, Savannah, and West Pearl Rivers, as shown in the following table.

An interesting occurrence in January, 1931, was the formation of an ice sheet at Saltair, near Salt Lake City, on Great Salt Lake. The sheet was observed on the morning of the 6th; it was about one-fourth inch thick, began at the shore, and extended out about 1,000 feet. This is the first known instance of the formation of ice on the open lake; a possible explanation of the cause of the freezing is given by Herman Harms, Utah State chemist, as follows:

> The prolonged cold spell has caused an unusually heavy precipitation of Glauber salts, one of the chief constituents next to sodium chloride. This has decreased the density of the water to such an extent as to permit freezing over the shallow water near the shore. The ordinary freezing point of Great Salt Lake water, which is nearly 23 per cent solid, would be from 20° to 25° below zero. With the density decreased by Glauber salts precipitation, however, the freezing point would be raised about 10°.

The freezing of Bear River Bay, a part of the lake, is said not to be unusual, but is due to an artificial condition. The embankment of the Lucin cut-off has almost completely separated Bear River Bay from the main body of the lake, and the water from Bear River freshens the bay water to an extent sufficient to allow freezing to take place. Also, considerable ice from Jordan River floats into the lake occasionally.

Table of flood stages in January, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Santee:	Feet			Feet	
Rimini, S. C.	12	20	22	12.2	22
Ferguson, S. C.	12	10	12	12.1	12
		14	25	12.7	18–19
Savannah: Ellenton, S. C.	13	8	11	14.3	9
		14	23	17.3	16
EAST GULF DRAINAGE					
West Pearl: Pearl River, La.	13	12	24	14.7	18

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

January is normally the stormiest month of the year over the North Atlantic. During the current month, however, the number of days with gales was considerably less than usual over the greater part of the ocean. The largest number of gales occurred over the region between the Bermudas and Maritime Provinces, where they were reported on from 2 to 5 days, while according to reports received, they did not occur on more than 4 days in any other 5° square.

As shown by Table 1, the average pressure at land stations in eastern Canada and Newfoundland was considerably below normal, while the North Atlantic HIGH was apparently well developed.

As in December, the number of days with fog was below the normal over practically the entire ocean. The maximum amount occurred in the square that includes the east coast of Newfoundland, where it was reported on seven days. Over the Grand Banks it was reported on from 4 to 5 days; over the steamer lanes, east of the fortieth meridian, on not more than one day in any 5° square; along the American coast, between the thirtieth and forty-fifth parallels, on from one to two days; in the Gulf of Mexico, on from one to two days.

Barometric data for several island and coast stations are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, January, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.54	(1)	30.28	11th	28.74	26th.
Belle Isle, Newfoundland	29.80	−[2] 0.20	30.10	6th [3]	28.98	17th.
Halifax, Nova Scotia	29.82	−[4] 0.16	30.28	19th	28.92	7th.
Nantucket	29.96	−[4] 0.09	30.34	25th	29.22	31st.
Hatteras	30.08	−[4] 0.06	30.50	16th	29.22	6th.
Key West	30.10	−[4] 0.01	30.36	15th	29.84	5th.
New Orleans	30.19	+[4] 0.03	30.60	15th	29.68	5th.
Cape Gracias, Nicaragua	29.94	−[2] 0.04	29.98	2d [3]	29.90	5th.[3]
Turks Island	30.10	+[2] 0.05	30.22	16th	30.00	6th.
Bermuda	30.06	−[4] 0.10	30.28	18th [3]	29.76	7th.[3]
Horta, Azores	30.23	+[2] 0.13	30.66	15th [3]	29.41	2d.
Lerwick, Shetland Islands	29.62	−[2] 0.08	30.48	7th	28.66	23d.
Valencia, Ireland	29.97	+[2] 0.07	30.53	9th	29.35	31st.
London	29.91	−[2] 0.09	30.52	7th	29.20	1st.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., 75th meridian time.
[3] And on other date or dates.
[4] From normals based on 8 a. m. observations.

Charts VIII to XI cover the period from the 1st to 4th, inclusive, and Charts XII and XIII show the conditions on the 10th and 11th, respectively. These two latter charts were drawn to give an idea of the weather encountered by the ill-fated airplane *Tradewind* that took off from Bermuda for the Azores on the morning of the 10th and was lost at sea.

On the 5th moderate conditions prevailed over the greater part of the ocean, although the land stations at Tampico and Vera Cruz, Mexico, reported northerly winds, force 7 and 8, respectively, with a barometric reading of 30.14 inches at both stations. On this date there was a depression over the northern section of the Gulf of Mexico, with a barometric reading of 29.60 inches at Pensacola that afterwards developed into a severe disturbance as it moved northeastward along the coast.

On the 6th this LOW was central near New York, where the barometer read 28.96 inches; on the 7th it was over the Maritime Provinces, barometer at Halifax 28.92 inches; on the 8th central near Belle Isle, barometer 29.03 inches. This disturbance reached its greatest extent and intensity on the 7th, when the storm area extended from the thirtieth to forty-fifth parallels, west of the fiftieth meridian, and winds of force 10 to 12 were reported by vessels during this period from the 6th to 8th. During this same period there was also a LOW that remained nearly stationary in the vicinity of the Azores, accompanied by moderate to whole gales, and on the 8th the station at Horta reported, wind NE, 11, barometer 29.58 inches. By the 9th this LOW had apparently filled in, as there are no signs of it on the chart for that day.

On the 9th a depression was central about 300 miles northwest of Bermuda that moved northward, increasing in intensity, and on the 10th was central near Sydney, Nova Scotia. On the 10th and 11th the region between the thirty-fifth and forty-fifth parallels was swept by gales from nearly all points of the compass, reaching hurricane force at times.

From the 12th to 14th moderate conditions prevailed over the greater part of the ocean, although vessels in widely separated localities reported winds of force 7 and 8.

From the 15th to 17th there was another active disturbance between the Bermudas and fiftieth parallel that reached its greatest intensity on the 16th, when central near 42° N., 54° W. Reports from vessels involved are given in table of gales and storms. On the 17th southerly gales were also reported by vessels over the middle section of the steamer lanes, and northwesterly winds of force 7 and 8 by vessels in the vicinity of and at land stations on the British Isles.

On the 20th a LOW was off the west coast of Cuba, with winds of a maximum force of 10, as shown by report in table. This disturbance moved slowly northward, gradually filling in, and on the 21st moderate weather prevailed along the American coast, except that one vessel near Nassau encountered a northerly wind, force 7.

On the 21st a disturbance was central near 51° N., 38° W., that moved slowly eastward, and by the 24th and 25th was over the North Sea.

On the 26th and 27th gales also occurred between the thirtieth and fiftieth parallels and the thirtieth and forty-fifth meridians.

On the 28th and 29th a depression over the British Isles was responsible for moderate westerly and northwesterly gales over a limited area between the coast and twentieth meridian.

On the 30th Halifax was near the center of a LOW that on the 31st was central near Belle Isle, and on both dates westerly to northwesterly gales were encountered by vessels between the thirty-fifth and fiftieth parallels, west of the forty-fifth meridian. On the 31st moderate southwest gales were also reported by land stations on the south coast of England.

NOTE—American steamship *Carplaka*, Capt. A. J. Griggs; observer, A. Rasmussen. From New York to Copenhagen:

On January 23, 1931, at 2.30 p. m., in latitude 57° 09′ N., longitude 23° 42′ W., observed a waterspout traveling from NW. to SE., overtaking vessel and crossing bow, vanishing in horizon in about 10 minutes. It appeared like dark smoke whirling apparently in a clockwise direction and extending about 100 feet above surface. Ship was steaming 74°, 13.5 knots an hour. This occurred during a hail squall of short duration, weather being clear with passing squalls. Barometer read 29.07 inches, air 39°, water 49°, wind WNW., 5, sea WNW, moderately rough.

OCEAN GALES AND STORMS, JANUARY, 1931

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Peter Kerr, Am. S. S.	London	Philadelphia	39 20 N	41 05 W	Dec. 30	4 a, 1	Jan. 3	29.08	WSW	W, 12	WNW	W, 12	Steady.
City of Alton, Am. S. S.	Antwerp	New York	44 25 N	40 20 W	Dec. 31	2 a, 1	Jan. 2	28.77	SSE	SW, 8	NNW	NNW, 12	SW-NW.
Motocarline, Belg. M. S.	Esbjerg	Baytown	41 59 N	27 52 W	Jan. 1	1 p, 1	do	29.33	SW	SW, 8	SW	SW, 10	Steady.
Coldwater, Am. S. S.	Antwerp	Charleston	32 48 N	65 58 W	do	2 a, 2	do	29.47	S	W, 10	N	—, 10	S-W-NW.
Collamer, Am. S. S.	Bordeaux	New York	35 20 N	58 00 W	Jan. 2	2 p, 2	do	29.37	S	SW, 10	NNW	SW, 10	SW-W-NW.
Emile Francqui, Fr. S. S.	Antwerp	do	45 05 N	45 30 W	Jan. 3	4 a, 3	Jan. 3	29.03	N	N, 12	N	N, 12	Steady.
McKeesport, Am. S. S.	Havre	do	47 48 N	28 00 W	do	2 a, 4	Jan. 4	29.12	SSE	S, 7	NW	NNW, 10	S-W-NNW.
Silverlarch, Br. M. S.	Genoa	do	36 23 N	68 13 W	Jan. 5	2 p, 6	Jan. 7	29.32	SSW	SW, 10	NW	SW, 10	SSW-WNW.
Peter Kerr, Am. S. S.	London	Philadelphia	36 20 N	59 50 W	Jan. 6	6 a, 7	Jan. 8	29.36	SW	WSW, 8	WNW	S, 12	SW-WSW.
Augustus, Ital. S. S.	Naples	New York	37 50 N	48 54 W	Jan. 7	4 p, 7	do	29.59	S	S, —	W	S, 11	S-W.
Peter Kerr, Am. S. S.	London	Philadelphia	37 05 N	64 05 W	Jan. 9	10 p, 9	Jan. 11	29.36	NNE	NNE, 10	NNW	NNE, 12	Steady.
Quaker City, Am. S. S.	Hull	do	42 31 N	61 20 W	Jan. 10	8 a, 10	do	29.53	ENE	ENE, 7	W	NW, 11	
Marie Leonhardt, Ger. S. S.	Antwerp	New York	36 01 N	73 22 W	Jan. 12	8 p, 12	Jan. 12	29.61	S	S, —	W	—, 11	
Bloomersdijk, Du. S. S.	Beaumont	Rotterdam	37 26 N	63 05 W	Jan. 15	3 p, 15	Jan. 16	28.80	WSW	WSW, 10	NW	NW, 12	WSW-WNW.
River Tigris, Br. S. S.	Gibraltar	New York	35 40 N	59 50 W	do	1 p, 15	do	29.51	W	W, —	NW	W, 12	W-NW.
Emile Francqui, Fr. S. S.	New York	Antwerp	41 42 N	55 00 W	do	4 a, 16	do	28.90	S	S, 11	SW	S, 11	S-SW.
Milwaukee, Ger. M. S.	Galway	New York	48 44 N	36 00 W	Jan. 17	10 a, 17	Jan. 18	29.55	SW	S, 11	WNW	S, 11	SW-S-WNW.
Amapala, Hond. S. S.	Canal Zone	New Orleans	25 10 N	87 20 W	Jan. 20	8 p, 20	Jan. 21	29.92	N	N, 9	N	N, 10	Steady.
Bellflower, Am. S. S.	New York	Glasgow	51 40 N	35 44 W	Jan. 21	5 p, 21	Jan. 22	29.32	NE	SSE, 7	W	W, 9	SSE-W.
Europa, Ger. S. S.	Cherbourg	New York	50 00 N	14 12 W	Jan. 23	11 a, 23	Jan. 23	29.32	SW	W, 10	W	W, 10	SW-WNW.
Bowes Castle, Br. S. S.	Galveston	Havre	38 48 N	62 24 W	Jan. 24	Mdt, 24	Jan. 25	29.93	NW	WNW, 10	N	—, 10	
Europa, Ger. S. S.	Cherbourg	New York	45 42 N	42 24 W	Jan. 25	1 a, 25	do	29.18	S	S, 9	NW	SW, 10	S-NW-WNW.
Rotterdam, Du. S. S.	Rotterdam	do	46 57 N	36 51 W	Jan. 26	9 a, 27	Jan. 28	29.64	SW	SW, 9	NW	SW, 9	
Bannack, Am. S. S.	Liverpool	Boston	51 20 N	24 30 W	Jan. 27	8 p, 29	Jan. 30	29.47	S	SSW, 8	NNW	—, 9	
Wytheville, Am. S. S.	New York	Rotterdam	50 51 N	32 00 W	Jan. 31	8 p, 31	Jan. 31	29.47	ESE	S, 9	SW	S, 9	ESE-SSW.
Express, Am. S. S.	Seville	New York	37 09 N	65 14 W	Jan. 30	Noon, 31	Feb. 1	29.47	NW	SW, 9	NW	SW, 10	
NORTH PACIFIC OCEAN													
President Grant, Am. S. S.	Yokohama	Seattle	50 13 N	173 41 W	Jan. 1	4 p, 5	Jan. 7	27.78	NNW	S, 8	SSW	ESE, 10	E-SE-SW.
Diana Dollar, Am. S. S.	Tobaco, P. I.	Los Angeles	38 24 N	171 23 E	do	11 p, 1	Jan. 2	29.63	W	W, 9	WNW	W, 10	1 point.
Arabia Maru, Jap. S. S.	Yokohama	Vancouver	49 43 N	134 10 W	Jan. 2	3 a, 3	Jan. 3	29.03	SE	SE, 8	SSE	WSW, 9	W-S-SSE.
Diana Dollar, Am. S. S.	Tabaco, P. I.	Los Angeles	41 09 N	174 40 W	Jan. 3	3 a, 4	Jan. 4	29.29	SSE	SSE, 10	W	W, 10	10 points.
Edgemoor, Am. S. S.	San Pedro	Yokohama	33 35 N	160 00 E	do	2 a, 4	do	29.48	SW	WNW, —	NW	NW, 9	WSW-NW.
Silverelm, Br. M. S.	Manila	San Francisco	39 21 N	170 07 E	do	6 a, 4		28.90	SE	SW, 12		—, 12	SW-W-WNW.
Bellingham, Am. S. S.	Hong Kong	do	44 40 N	168 30 E	do	7 a, 4	Jan. 6	28.66	E	NNE, 10	SW	W, 10	4 points.
Scalaria, Br. S. S.	Kobe	San Pedro	47 06 N	175 15 W	do	Noon, 4	Jan. 8	28.06	SE	SW, 10	SW	SW, 12	WSW-S-SW.
Northwestern, Am. S. S.	Seattle	Seward	58 14 N	137 16 W	Jan. 4	2 a, 4	Jan. 4	28.92	NE	NE, 7	N	NE, 9	NE-N.
Golden Peak, Am. S. S.	Shanghai	San Francisco	40 25 N	164 55 W	do	11 a, 4	Jan. 5	29.29	SE	S, 9	W	S, 9	SE-S-W.
Emma Alexander, Am. S. S.	San Diego	Seattle	45 00 N	124 50 W	Jan. 5	6 a, 5	do	29.21	SE	Calm	NW	NW, 12	SE-NW.
Empress of Canada, Br. S. S.	Yokohama	Vancouver	49 23 N	167 15 W	do	1 p, 6	Jan. 7	28.19	SW	SW, 11	SSW	SW, 11	SSE-S-SW.
San Pedro Maru, Jap. M. S.	Takao	San Francisco	36 08 N	152 03 E	Jan. 6	6 p, 10	Jan. 12	29.18	NE	SW, 6	NW	S, 10	NE-E-S.
Arizona Maru, Jap. S. S.	Yokohama	Victoria	50 12 N	156 35 W	Jan. 9	8 p, 9	Jan. 10	28.83	SE	SSW, 9	SSW	SSW, 9	SE-SW-SSW.
Kentucky, Am. S. S.	Hong Kong	San Francisco	28 29 N	129 18 E	do	4 p, 9	do	29.84	NW	NW, 4	NW	NW, 9	Steady.
Scalaria, Br. S. S.	Kobe	San Pedro	43 50 N	145 40 W	Jan. 10	10 p, 10	Jan. 11	29.30	SE	S, 7	WNW	W, 9	SE-S-WNW.
Choyo Maru, Jap. S. S.	Miike	Seattle	46 38 N	176 36 E	Jan. 11	Mdt, 11	do	29.07	S	SW, 3	SW	SE, 10	8 points.
Nora, Am. S. S.	San Pedro	Yokohama	30 41 N	156 35 E	Jan. 14	Noon, 14	Jan. 14	29.83	SW	SW, 9	W	W, 10	SW-W.
Golden Star, Am. S. S.	Hong Kong	San Francisco	40 28 N	154 51 W	do	2 p, 15	Jan. 15	29.28	S	S, 5	NW	S, 11	S-W-NW.
Choyo Maru, Jap. S. S.	Miike	Seattle	49 08 N	158 07 W	do	4 p, 15	Jan. 17	28.43	S	S, 4	SE	SE, 11	4 points.
San Pedro Maru, Jap. M. S.	Takao	San Francisco	38 34 N	178 50 E	do	4 p, 15	Jan. 15	29.02	SE	WSW, 8	NW	W, 11	SE-SW-NW.
Holystone, Br. S. S.	Panama	Vancouver	43 22 N	125 00 W	Jan. 15	3 p, 15	Jan. 16	29.89	S	SW, 7	NW	W, 10	S-SW-W.
City of Victoria, Can. S. S.	Japan	Port Alice	50 37 N	161 58 W	do	6 p, 15	Jan. 17	28.19	ESE	SE, 7	ESE	ESE, 9	SE-ESE.
Sbabonee, Br. S. S.	Manila	San Pedro	35 52 N	166 11 W	do	9 p, 15	do	29.14	S	—, 10	NW	—, 10	S-SW-W.
Golden Star, Am. S. S.	Hong Kong	San Francisco	40 45 N	148 37 W	Jan. 16	5 a, 16	do	29.58	SW	SE, 8	W	SE, 9	S-SW-W.
Sbabonee, Br. S. S.	Manila	San Pedro	35 52 N	149 30 W	Jan. 18	—, 19	Jan. 19	29.14	S	—, —	NW	—, 11	SSW-W-WNW.
Hanover, Am. S. S.	do	do	39 55 N	166 00 W	Jan. 21	5 a, 22	Jan. 22	29.12	S	S, 8	S	S, 9	Steady.
Admiral Watson, Am. S. S.	San Francisco	Portland, Oreg	43 49 N	124 23 W	do	10 p, 21	Jan. 23	29.60	SE	—, 8	S	—, 9	SE-S.
San Diego Maru, Jap. M. S.	Elwood	Kudamatsu	32 35 N	138 45 E	Jan. 22	3 p, 23	do	29.71	S	WSW, 8	NW	SW, 9	WSW-NW.
Modjokerto, Du. S. S.	Menato	Los Angeles	33 30 N	141 30 W	Jan. 23	Noon, 24	Jan. 24	29.68	S	SW, 9	SW	SW, 9	S-SW-WSW.
Nora, Am. S. S.	Yokobama	San Pedro	35 02 N	148 00 E	do	8 a, 23	Jan. 25	29.72	S	S, 7	NW	W, 9	W-NW.
Hakubasan Maru, Jap. M. S.	do	San Francisco	46 25 N	174 00 W	Jan. 24	3 p, 27	Jan. 28	28.43	ESE	SSE, 8	SSW	SSW, 9	ESE-S-WSW.
Paul Luckenbach, Am. S. S.	New York	San Pedro	15 25 N	94 35 W	do	4 p, 24	Jan. 25	29.81	NW	N, 9	NW	—, 9	NW-N-NNE.
William Penn, Am. M. S.	Iloilo, P. I.	do	30 22 N	166 32 E	do	6 p, 25	Jan. 26	29.69	WSW	WNW, 7	WNW	—, 9	WNW-WSW.
Emidio, Am. S. S.	Richmond Beach, Wash.	do	44 55 N	124 30 W	Jan. 25	6 a, 25	Jan. 25	29.77	S	S, 9	SSW	SSW, 9	S-SSW.
Hye Maru, Jap. M. S.	Yokohama	Victoria	45 27 N	163 09 E	Jan. 26	1 a, 28	Jan. 28	28.02	ESE	S, 6	S	WSW, 10	SE-SW.
Makua, Am. S. S.	Columbia River.	Honolulu	36 00 N	141 15 W	Jan. 27	8 p, 27	do	29.50	SE	SE, 10	SW	—, 10	SE-SW.
Ixion, Br. S. S.	Yokohama	Victoria	49 20 N	178 12 W	do	7 p, 27	Jan. 29	27.99	E	E, 6	S	ENE, 10	SE-E-S.
Wisconsin, Am. S. S.	Japan	San Francisco	47 35 N	179 30 W	do	7 a, 29	do	28.02	SE	W, 4	W	W, 9	SE-NW-NE.
Ohioan, Am. S. S.	Los Angeles	New York	Morro Ayuca, L. H.		Jan. 29	4 p, 29	do	29.88	NNE	NNE, 8	N	NNE, 9	NNE-N.
Northwestern, Am. S. S.	Seattle	Seward	60 35 N	146 00 W	do	2p, 29	do	29.08	E	E, 7	NE	E, 9	E-NE.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—During December, 1930, pressure showed a great tendency to fall in the Aleutian region. The descent continued in January, and for this month unprecedentedly low averages occurred over the Alaskan Peninsula and neighboring islands. At Dutch Harbor, with a maximum daily barometric reading of 29.68 inches and a minimum of 28.22, the average for the first time on record for any month was below 29 inches and more than six-tenths of an inch below the normal. Between Dutch Harbor, with 28.94 inches, and Honolulu, where the average was 30.07, there existed a mean gradient for the month of 1.13 inches. The LOW extended well into the central Pacific, and as a consequence the usual anticyclone of middle latitudes was generally unstable and much restricted in area. On the average

it covered the coastal waters of the United States from Oregon to Lower California and the major part of the ocean otherwise between the fifteenth and thirtieth parallels.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, January, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	30.06	−0.02	30.72	21st	29.60	8th.
Dutch Harbor [1]	28.94	−0.64	29.68	4th	28.22	6th.
St. Paul [1]	29.07	−0.56	29.76	4th	28.44	7th.
Kodiak [1]	29.11	−0.48	29.60	17th	28.66	14th.
Midway Island [1]	29.99	−0.04	30.26	10th [3]	29.64	25th.
Honolulu [2]	30.07	+0.07	30.26	1st	29.88	26th.
Juneau [2]	29.62	−0.26	30.26	17th	28.97	4th.
Tatoosh Island [2] [4]	29.94	0.00	30.48	17th	29.33	22d.
San Francisco [2] [4]	30.12	+0.03	30.32	16th	29.75	7th.
San Diego [2] [4]	30.07	+0.01	30.32	4th	29.80	6th.

[1] Averages from p. m. observations only.
[2] A. m. and p. m. observations.
[3] And on the 11th.
[4] Corrected to 24-hour mean.

NOTE.—Beginning with January, 1931, new normals of atmospheric pressure are in use for Midway Island and the Alaskan substations appearing in this table. For Dutch Harbor, St. Paul, Kodiak, and Midway Island the average covers a period of 12 years and for Point Barrow 8 years. Data are compiled to include the year 1928.

January, 1931, was peculiarly a stormy month on the North Pacific Ocean and no day passed without gales in some portion of the sea, although they were generally well distributed over all the region from the thirtieth parallel northward. According to reports already received wind forces of 11 to 12 occurred on at least 10 days of the month, and forces of 10—whole gales—on more than half the days, in many cases blowing simultaneously in connection with widely separated disturbances. The tabular statement—Ocean gales and storms—presents a picture of the general storminess, showing gales of force 9 and upward, which needs no fuller amplification in text.

Several of the important local gales of major storm force were associated with the activities of the Aleutian LOW; some were due to the sharp expansion of the cyclone region against the immediately outlying anticyclone, which resulted in the formation of sudden steep barometric gradients, while others accompanied the more powerful of the progressive cyclones.

The severest cyclone of the month originated south of Japan on the 1st or 2d and began moving rapidly northeastward. By the 3d, then central at some distance southeast of the Kuril Islands, it attained hurricane intensity. On the 4th, south of the central Aleutians, it was causing dangerous gales over a great region along the upper routes between 160° E. and 170° W. On the 5th and 6th, now of great depth and continuing high wind intensity, it crossed the eastern Aleutians. The following three days witnessed its rapid decadence as it contracted in area and wandered aimlessly over the eastern waters of the Bering Sea. This storm was remarkable for its extremely low central pressure during the 4th and 5th, corrected barometer readings from the American steamer *President Grant* running below 28 inches for several hours, the minimum being 27.78, in 50° 13′ N., 173° 41′ W., on the 5th.

On the 5th, also, on the eastern extremity of the general Aleutian disturbance, hurricane velocities from the northwest occurred off the Washington coast near North Head, and strong to storm gales, mostly southerly, were encountered off this and the Oregon coast on the 21st, 22d, and 25th. A maximum velocity of 67 miles an hour from the south was recorded on the 22d at the Weather Bureau station on Tatoosh Island.

Midway along the sailing routes between the United States and Honolulu gales of force 8 to 10 occurred on 8 or more days, this region being unusually stormy. The period of most prolonged storminess here was from the 23d to 27th.

As indicative of the unusually long-sustained southward extension of the storm area for January this year, it is necessary only to remark that gales of force 8 to 10 occurred at various times and in various longitudes on about half the days of the month even in as low a latitude as that of the thirtieth parallel, a fact that, in the opinion of the writer, can not be duplicated by any other month of record.

In the China Sea one typhoon—the only North Pacific tropical cyclone of the month—was a brief disturbing weather factor. This is treated in the subjoined article. The northeast monsoon, however, blew at times with fresh gale force on several days, particularly on the 10th to 16th west of the Philippine Islands.

In and near the Gulf of Tehuantepec northers of gale force—8 to 10—were unusually frequent, occurring on at least 12 days of the month.

Strong northeast trades, rising to moderate gale force, were reported by the American steamer *Sierra* between 1° and 15° north latitude south of the Hawaiian Islands on the 13th to 15th.

At Honolulu the wind was generally light with prevalence from the east. The maximum velocity was 24 miles an hour from the northeast on the 18th.

Fog was rarely encountered on the Pacific this month except along or at no great distance from the coasts. Vessels up to time of this writing (March 2) have reported fog off the China coast on 6 days and in American waters between Vancouver and San Diego on 11 days.

TYPHOONS AND DEPRESSIONS

FIRST DESTRUCTIVE TYPHOON OVER THE PHILIPPINES IN 1931, JANUARY 3 AND 4

By REV. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

The Philippines have been visited at the beginning of this year by a very destructive typhoon, more severe than any of the typhoons experienced in our archipelago during the past year, 1930. Taking into consideration the Provinces most affected by this typhoon, it can be compared with that of October 15, 1912, although it was not so deep and of much less extension. Yet great damage was done to the crops and to the public and private properties, thousands of people remained homeless, besides a considerable loss of life that has been reported from several Provinces.

The typhoon was probably formed on December 30, 1930, nearly 300 miles to the south of Guam in about 145° longitude E. and 9° latitude N. It moved W. by N. and passed near to the north of Yap at 11 p. m. of December 31 when a barometric minimum of 749 mm. (29.49 ins.) was recorded with winds from W., force 5. From 2 to 10 p. m. of January 2 the typhoon took a WSW. direction: hence instead of entering the Philippines through the southern part of Samar, as it could be anticipated, it

came to pass through the Surigao Strait between Surigao and the southern coast of Samar. After 10 p. m. of the 2d the typhoon moved again to WNW. and W. by N. toward the central part of Leyte and the northern part of Cebu and Panay Islands. From Panay the typhoon moved northwest toward the southern coast of Mindoro and then into the China Sea, when it gradually filled up on the 5th or 6th in the neighborhood of the Paracels.

The barometric minimum reported from our stations was that of Dumalag, Capiz, 737 mm. (29.02 ins.) with winds veering from NW. to N., NE., E., and S. Relative calm was observed at Tuburan, Cebu, between 8.30 and 8.40 a. m. of the 3d.

The rate of progress of this typhoon was far from being uniform; because while from 2 to 6 a. m. of the 3d it moved at the heavy rate of about 20 miles per hour, from 6 a. m. to 2 p. m. of the same day the rate was slightly over 11 miles per hour.

The approximate positions of the center of this typhoon from December 31 to January 5 were as follows:

December 31, 6 a. m., 142° 20′ longitude E., 9° 20′ latitude N.
December 31, 11 p. m., 138° 15′ longitude E., 9° 50′ latitude N.
January 1, 6 a. m., 135° 45′ longitude E., 10° 10′ latitude N.
January 2, 6 a. m., 130° 45′ longitude E., 10° 40′ latitude N.
January 2, 10 p. m., 126° 25′ longitude E., 10° 10′ latitude N.
January 3, 2 a. m., 125° 40′ longitude E., 10° 25′ latitude N.
January 3, 6 a. m., 124° 20′ longitude E., 10° 50′ latitude N.
January 3, 2 p. m., 122° 50′ longitude E., 11° 10′ latitude N.
January 4, 6 a. m., 120° 40′ longitude E., 12° 25′ latitude N.
January 5, 6 a. m., 116° 50′ longitude E., 15° 30′ latitude N.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By Giles Slocum

STRAITS OF FLORIDA AND CARIBBEAN SEA

With the January, 1931, issue of the Monthly Weather Review is initiated the monthly publication of a summary of Greenwich mean noon "Bucket observations" of temperatures at the surface of the water for the month one year preceding the date borne by the issue, in the Straits of Florida and the Caribbean Sea.

The "Caribbean Sea" is here defined as the area included between the American Continents on the south and west and the Greater Antilles and outermost Lesser Antilles on the north and east. The entire Mona Passage, the Windward Channel south of 20° N., and the Yucatan Channel north to 22° N., west on this parallel to 87° W., and south to the Yucatan Peninsula, are included, but observations from Lake Maracaibo are omitted.

The "Straits of Florida" data refer to the area bounded on the east by the eightieth meridian, on the north by the twenty-fifth parallel, on the west by the eighty-fourth meridian, and on the south by the Cuban coast.

As is well known, the method of taking bucket observations consists of drawing up with a canvas bucket thrown over the side of the ship a sample of the water near the surface. The temperature of this sample is immediately taken with a mercurial thermometer and recorded on the proper form. In a small but unknown number of cases other methods, such as measurement of the temperature at the condenser intake, are used by the mariners.

The variation of weather conditions from day to day have modifying effects on the temperatures of the water surface and, while the number of measurements of these temperatures within a stated area in any one day is, to a considerable degree, due to elements of chance, and subject to wide fluctuations. The truest mean temperature, then, will not result from weighting equally either the individual observations or those collectively of the single days, and a longer unit-period of time is needed.

The month, therefore, has been divided into four nearly equal "Quarters," each quarter embracing a period of either seven or eight days, as shown in Table 1. The mean of the averages of the four quarters is adopted as the mean temperature for the area during the month.

This gives a uniform method of computing the means for months of unequal length. The quarter-month is a period short enough to practically exclude, in tropical and subtropical latitudes, any seasonal march between its beginning and its end, but is yet long enough to smooth out daily chance fluctuations in the number of observations taken, and to make their number within each period of the same order of magnitude, justifying the assigning of roughly equal weights to them.

In computing the means for each 5-degree square in the Caribbean, however, the use of this refinement is not possible, and the means used are the sums of the temperatures for the months divided by the numbers of observations.

From this, it is obvious than an even greater number of observations than is available would be highly desirable, and, lacking this greater number, it is important that no genuinely pertinent information be neglected to round out the data, but such observations as are taken in port are not used because of various factors affecting their direct comparability with those taken on the open seas.

On this basis, and subject to these limitations, Table 2 shows the mean temperature for the Caribbean Sea and the Straits of Florida for January of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same area, including the departures of the January, 1930, means from the 11-year means for January (1920–1930), and the changes from the temperatures for the preceding month of December, 1929.

The means for 1919, it will be noted, are not used in the computations or comparisons, the poor distribution and dearth of data for that year making them somewhat unreliable.

The chart at the end of this article shows the number of observations taken during the month of January, 1930, within each 1° square; the mean temperatures of the Straits of Florida and of each 5° [1] square in the Caribbean Sea; the 11-year means (1920–1930), for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

Table 1.—*Lengths of "Quarter months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[1] In three cases, indicated on the chart, the observations from small, little traveled, and unimportant areas have been treated as parts of the contiguous 5° squares.

TABLE 2.—*Mean surface temperatures in the Caribbean Sea and the Straits of Florida for January, 1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	14	78.7	11	75.4
1920	113	79.2	22	73.6
1921	192	78.8	58	75.2
1922	216	79.0	79	74.9
1923	270	78.0	74	75.1
1924	353	78.7	87	75.8
1925	272	79.0	123	75.8
1926	314	79.7	133	74.5
1927	318	79.3	156	74.6
1928	403	79.0	134	73.7
1929	519	79.2	136	75.2
1930	538	78.7	153	75.6
Mean (1920–1930)		79.0		74.9

[1] Not used in computations because of insufficient data available.

TABLE 3.—*Mean sea-surface temperatures (°F.), and number of observations, January, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean (° F.)	Departure from 11-year mean (1920–1930) (° F.)	Change from preceding month (° F.)	Number of observations	Mean (° F.)	Departure from 11-year mean (1920–1930) (° F.)	Change from preceding month (° F.)
I	Jan. 1–7	124	79.0			43	75.3		
II	Jan. 8–15	131	78.8			42	75.8		
III	Jan. 16–23	135	78.8			34	76.3		
IV	Jan. 24–31	148	78.2			34	74.9		
Month		538	78.7	−0.3	−1.4	153	75.6	+0.7	−1.1

CLIMATOLOGICAL TABLES

DESCRIPTION OF TABLES AND CHARTS

Table 1 gives the data ordinarily needed for climatological studies for about 184 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, seventy-fifth meridian time, and for about 32 others making only one observation. The altitudes of the instruments above ground are also given.

Beginning January 1, 1928, movement and velocity of the wind are printed as recorded by the 3-cup anemometer, which has replaced the 4-cup pattern.

Table 2 gives, for about 37 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, **30:** 13–16.

CHART I.—*Temperature departures.*—This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909, but smaller charts appear in W. B. Bulletin U for 1873 to June, 1909, inclusive.

CHART II.—*Tracks of centers* of ANTICYCLONES; and

CHART III.—*Tracks of centers* of CYCLONES. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month, the location indicated being that at 8 a. m., seventy-fifth meridian time. Within each circle is also an entry of the last three figures of (Chart II) the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, in both cases as reduced to sea level and standard gravity. The intermediate 8 p. m. locations are indicated by dots. The inset map of Chart II shows the departure of monthly mean pressure from normal and the inset of Chart III shows the change in mean pressure from the preceding month.

The use of a new base map for Charts II and III began with the January, 1930, issue.

CHART IV.—*Percentage of clear sky between sunrise and sunset.*—The average cloudiness at each regular Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

CHART V.—*Total precipitation.*—The scales of shading with appropriate lines show the distribution of the monthly precipitation according to reports from both regular and cooperative observers. The inset on this chart shows the departure of the monthly totals from the corresponding normals, as indicated by the reports from the regular stations.

CHART VI.—*Isobars at sea level, average surface temperatures, and prevailing wind directions.*—The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow in the REVIEW for January, 1902, **30:** 13–16. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation.

The diurnal corrections so applied, except for stations established since 1901, will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at almost all the stations. A few stations determine their prevailing directions from the daily or twice-daily observations only.

CHART VII.—*Total snowfall.*—This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines connecting places of equal snowfall, but in special cases figures also are given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation. The inset of this chart, when included, shows the depth of snow on the ground at the end of the month.

CHARTS VIII, IX, etc.—*North Atlantic Weather maps of particular days.*

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1931

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	45.0	−1.0	Brewton (near)	78	28	Riverton	11	15	3.10	−1.88	Mobile	5.43	Madison	1.80
Arizona	42.8	−0.3	3 stations	84	[1] 22	Ganado	−8	5	0.47	−0.72	Oracle	1.70	10 stations	0.00
Arkansas	42.3	+1.3	4 stations	76	[1] 25	Corning	0	15	1.14	−3.10	El Dorado	3.40	Harrison	T.
California	45.4	+1.2	King City	89	4	Twin Lakes	−6	8	4.14	−1.32	Kennett	13.92	2 stations	T.
Colorado	25.0	+1.6	2 stations	70	29	Sunbeam	−28	16	0.17	−0.72	Savage Basin	2.00	27 stations	0.00
Florida	56.4	−2.5	5 stations	83	[1] 5	Mount Pleasant	20	15	3.38	+0.56	Miami	7.07	Hypoluxo	1.15
Georgia	46.1	−0.6	Quitman	78	[1] 25	Clayton	11	2	2.91	−1.30	Americus	4.15	Meldrim	1.50
Idaho	24.1	+1.6	Lapwai	58	28	3 stations	−22	[1] 1	1.41	−0.74	Roland	5.67	Twin Falls Factory	0.05
Illinois	33.2	+6.5	Carbondale	74	30	Freeport	−11	21	0.57	−1.75	Grand Chain	1.33	Griggsville	0.11
Indiana	33.2	+4.8	2 stations	69	[1] 24	Valparaiso	−11	15	0.80	−2.33	Valparaiso	2.68	Whiting	0.22
Iowa	28.9	+10.4	do	64	[1] 24	Decorah	−15	21	0.50	−0.57	Waverly	0.97	Lake Park (near)	T.
Kansas	36.4	+7.0	Ashland	75	24	2 stations	−4	14	0.26	−0.36	Le Roy	1.57	13 stations	0.00
Kentucky	37.7	+2.3	2 stations	72	[1] 26	Lovelaceville	−9	15	1.23	−3.12	Bowling Green (No. 2).	3.21	Anchorage	0.37
Louisiana	49.7	−1.6	3 stations	77	28	3 stations	21	15	5.83	+1.13	Grand Coteau	11.28	Tallulah	2.74
Maryland-Delaware	34.6	+1.7	do	66	[1] 25	Oakland, Md	−8	22	1.72	−1.50	Darlington, Md	2.35	Picardy, Md	0.71
Michigan	25.2	+5.2	2 stations	52	25	Wolverine	−20	7	1.26	−0.62	Ada	2.75	Traverse City	0.51
Minnesota	20.8	+13.0	Canby	60	29	Big Falls	−31	14	0.17	−0.58	Pigeon River Bridge	1.52	13 stations	T.
Mississippi	45.8	−1.2	Brookhaven	79	27	Holly Springs	13	15	3.54	−1.44	Magnolia	7.82	Hernando	1.13
Missouri	36.0	+5.5	2 stations	76	[1] 29	Goodland	−5	15	0.69	−1.35	Marble Hill	2.12	Fulton	0.07
Montana	28.6	+10.3	4 stations	69	29	Frazer	−26	13	0.35	−0.57	Heron	5.25	Savage	0.00
Nebraska	32.2	+10.7	Franklin	73	29	Gordon	−12	14	0.22	−0.33	Newport	1.00	12 stations	0.00
Nevada	31.6	+1.5	Logandale	84	28	Beowawe	−14	4	0.47	−0.65	Marlette Lake	3.57	2 stations	0.00
New England	21.8	−0.5	2 stations	55	27	St. Albans, Vt	−32	25	2.85	−0.53	Kingston, R. I	4.86	Bethleham, N. H	0.76
New Jersey	31.6	+1.8	Tuckerton	64	27	Layton	−5	[1] 2	2.16	−1.46	Bayonne	4.35	Newton	1.37
New Mexico	31.9	−0.9	Fort Sumner	72	31	Gavilan	−22	5	0.45	−0.09	Carson Scep Ranger station.	1.93	5 stations	0.00
New York	23.6	+1.0	2 stations	57	27	2 stations	−27	24	2.42	−0.49	Gabriels	4.68	Ogdensburg	0.64
North Carolina	41.0	−0.2	3 stations	75	[1] 25	Louisburg	1	16	2.21	−1.66	Beaufort	4.05	Elizabeth City	0.50
North Dakota	21.4	+15.2	Carson	68	29	Towner	−31	13	0.15	−0.32	Steele	0.91	4 stations	0.00
Ohio	31.8	+3.9	2 stations	66	25	2 stations	−2	15	1.23	−1.68	Jefferson	2.42	Chillicothe	0.58
Oklahoma	42.1	+4.0	Chandler	78	30	Pawhuska	8	14	0.64	−0.76	Hennessey	1.23	2 stations	0.00
Oregon	34.7	+3.5	2 stations	72	[1] 28	Austin	−11	8	2.63	−1.03	Valsetz	17.70	Bear Creek	T.
Pennsylvania	30.0	+2.1	Hyndman	65	25	Gouldsboro	−12	23	1.46	−1.79	Pleasant Mount	2.66	2 stations	0.49
South Carolina	44.5	−1.0	Yemassee	76	31	Clemson College	10	16	2.58	−0.92	Pinopolis	3.55	Darlington	1.42
South Dakota	28.6	+13.1	Academy	72	29	La Delle	−22	14	0.23	−0.40	Hardy Ranger station.	1.11	9 stations	T.
Tennessee	39.5	+0.8	Hall's Hill	74	30	Rogersville	−2	16	1.83	−2.91	Rugby	2.90	Bristol	0.47
Texas	48.5	+0.3	Presidio	85	31	Dalhart	8	11	2.81	+0.99	Bon Wier	7.49	Pampa	0.06
Utah	22.4	−2.3	St. George	72	29	Duchesne	−18	10	0.39	−0.87	Silver Lake	1.52	2 stations	0.00
Virginia	38.1	+2.0	Diamond Springs	73	28	Callaville	−2	16	1.58	−1.77	Diamond Springs	3.09	Monterey	0.27
Washington	35.7	+6.2	2 stations	70	[1] 28	Bumping Lake	−2	7	6.68	+0.83	Wynoochee Oxbow	31.80	Irene Mountain	0.84
West Virginia	33.7	+1.7	Cairo	71	25	2 stations	−10	2	1.37	−2.49	Pickens	4.09	Upper Tract	0.65
Wisconsin	23.9	+9.9	Big St. Germain Dam.	52	6	Hillsboro	−21	21	0.69	−0.47	Mauston	1.62	Amery	0.08
Wyoming	23.6	+5.1	2 stations	71	29	Buffalo Ranch	−25	20	0.24	−0.64	Bechler River	2.30	6 stations	0.00
Alaska (December)	14.9	+9.5	Mile Seven (Cordova).	58	1	Rampart	−39	15	3.94	+1.33	Ketchikan	35.16	Rampart	0.13
Hawaii	69.5	+1.0	Waipahu	88	14	Volcano Observatory.	43	21	2.08	−7.28	Kukaua	9.74	12 stations	0.00
Porto Rico	74.3	+1.0	San German	94	6	Guineo Reservoir	46	9	1.54	−2.04	Rio Blanco	9.98	Santa Rita (No. 3)	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							25.6	+1.1										72	3.04	-0.4										5.1		
Eastport	76	67	85	29.77	29.86	-0.14	21.8	+1.4	42	13	30	-6	25	14	38	20	15	74	2.90	-1.1	14	8,321	nw.	52	e.	6	11	4	16	6.2	12.2	2.4
Greenville, Me	1,070	6	----	28.67	29.89	----	13.8	----	40	27	23	-13	24	4	33	----	----	----	2.97	----	9	5,961	nw.	----	----	----	14	11	6	----	29.8	----
Portland, Me	103	82	117	29.80	29.93	-.12	25.2	+2.8	47	4	33	1	25	18	24	21	14	64	3.22	-0.8	10	5,693	w.	25	ne.	6	17	6	8	4.1	16.0	9.6
Concord	289	70	79	29.59	29.92	-.13	21.9	+0.3	50	27	32	-8	23	12	45	----	----	----	1.73	-1.3	7	3,857	nw.	21	nw.	7	14	8	9	4.5	20.3	16.8
Burlington	403	11	48	29.50	29.97	-.68	15.8	-3.0	38	27	25	-18	25	7	46	----	----	----	2.49	+0.7	16	6,540	s.	38	s.	25	4	12	15	6.9	31.3	16.0
Northfield	876	12	60	28.98	29.97	-.08	14.0	-1.2	44	27	26	-24	25	2	57	12	9	84	1.91	-0.4	10	3,819	n.	23	nw.	7	6	14	11	6.2	23.2	16.5
Boston	125	106	165	29.79	29.94	-.11	30.6	+2.7	55	27	38	7	15	23	27	26	20	65	4.09	+0.5	8	5,804	nw.	22	ne.	6	14	12	5	4.2	11.7	7.4
Nantucket	12	14	90	29.90	29.91	-.13	33.0	+1.7	53	6	40	14	25	26	26	30	26	79	3.23	-0.5	10	10,509	w.	42	ne.	5	9	7	15	5.9	5.9	4.0
Block Island	26	11	46	29.91	29.94	-.13	32.2	+1.2	52	6	38	11	15	26	26	29	24	71	3.81	0.0	9	13,341	w.	50	w.	7	12	11	8	5.3	4.6	2.2
Providence	160	215	251	29.76	29.95	-.11	29.8	+2.6	51	27	37	9	15	22	26	26	19	65	3.42	-0.3	8	8,340	nw.	40	nw.	7	16	9	6	4.2	12.0	7.0
Hartford	159	122	----	29.79	29.98	-.09	27.9	+2.4	53	27	35	5	15	21	24	----	----	----	3.46	-0.5	7	----	nw.	----	----	----	12	13	6	4.3	12.9	7.5
New Haven	106	74	153	29.86	29.98	-.10	29.7	+1.5	48	4	37	7	15	23	20	26	21	70	3.17	-0.8	7	5,693	nw.	28	nw.	7	16	10	5	4.1	2.5	2.0
Middle Atlantic States							34.9	+2.5										70	1.87	-1.4										5.3		
Albany	97	107	115	29.89	30.00	-.07	24.0	+0.9	45	27	32	-2	25	16	33	21	16	72	2.26	-0.1	7	4,555	s.	19	s.	25	7	16	8	5.5	14.7	9.2
Binghamton	871	10	84	29.04	30.00	-.08	24.8	+0.7	48	27	33	-1	2	16	33	----	----	----	2.19	-0.3	15	4,100	nw.	22	nw.	7	4	7	20	7.7	15.7	4.8
New York	314	414	454	29.65	30.00	-.10	33.2	+2.3	55	27	40	11	15	26	23	29	22	64	2.43	-1.2	6	11,747	nw.	51	nw.	6	9	14	8	5.3	0.7	0.0
Bellefonte	1,050	5	36	28.87	30.02	----	28.0	----	51	25	37	1	3	19	42	24	21	81	1.01	----	9	----	sw.	36	w.	21	4	12	15	6.8	4.6	0.0
Harrisburg	374	94	104	29.64	30.05	-.05	33.1	+4.1	56	27	40	14	15	27	25	28	21	64	1.82	-1.3	5	4,795	w.	26	w.	31	10	12	9	5.5	1.5	0.0
Philadelphia	114	123	367	29.90	30.04	-.07	36.2	+3.6	56	27	42	16	15	30	19	31	22	57	2.17	-1.1	4	8,903	nw.	40	nw.	7	11	8	12	5.2	0.1	0.0
Reading	325	81	98	29.67	30.04	----	33.2	+3.8	56	27	40	13	15	26	24	29	23	68	2.16	-1.4	4	4,297	nw.	28	e.	5	11	12	8	5.3	0.3	0.0
Scranton	805	111	119	29.13	30.02	-.07	27.8	+1.2	50	27	35	7	2	20	26	25	20	76	1.37	-1.7	10	4,558	sw.	25	nw.	31	4	15	12	6.3	4.5	T.
Atlantic City	52	37	172	29.96	30.02	-.09	36.1	+3.6	54	27	43	16	16	29	24	31	26	71	2.06	-1.4	4	11,147	w.	44	e.	5	13	7	11	4.9	0.0	0.0
Cape May	17	13	49	----	----	----	36.5	+2.4	59	27	44	18	15	30	21	33	29	82	1.71	-1.7	6	----	nw.	----	----	----	15	7	9	----	T.	0.0
Sandy Hook	22	10	55	29.96	29.99	----	32.9	----	52	27	39	14	15	27	19	29	24	73	2.27	-1.7	5	10,372	nw.	44	nw.	6	18	6	7	4.1	0.6	0.0
Trenton	190	159	183	29.81	30.02	----	33.2	+2.7	60	27	41	14	15	26	28	29	22	66	2.15	-1.2	4	6,918	nw.	35	nw.	7	11	11	9	5.1	T.	0.0
Baltimore	123	100	215	29.90	30.04	-.08	38.1	+4.3	64	27	45	19	16	31	26	32	26	64	1.89	-1.6	5	6,547	sw.	36	w.	31	12	9	10	4.9	1.1	0.0
Washington	112	62	85	29.92	30.05	-.08	37.0	+3.6	64	27	45	16	16	29	27	31	24	62	1.56	-2.0	5	4,128	nw.	30	nw.	7	11	9	11	5.5	T.	0.0
Cape Henry	18	8	54	30.03	30.05	----	41.4	+1.2	69	27	48	22	16	35	24	37	33	78	1.62	-1.5	6	8,078	sw.	38	nw.	15	14	6	11	4.7	0.4	0.0
Lynchburg	681	153	188	29.31	30.07	-.06	40.5	+3.0	67	25	50	15	16	31	36	34	28	64	1.48	-2.0	5	5,018	w.	29	nw.	6	18	2	11	4.8	1.4	0.0
Norfolk	91	170	205	29.97	30.07	-.06	42.4	+1.8	67	27	50	20	16	34	27	36	30	67	1.57	-1.5	5	8,287	nw.	36	nw.	6	15	3	13	4.7	2.5	0.0
Richmond	144	11	52	29.91	30.07	-.07	39.7	+1.8	65	27	50	10	16	29	38	34	29	72	1.88	-1.3	4	4,743	sw.	27	sw.	30	15	9	7	4.3	1.5	0.0
Wytheville	2,304	49	55	27.63	30.09	-.05	35.2	+2.2	56	25	43	9	2	28	38	30	25	71	1.03	-2.0	8	5,574	w.	26	w.	30	13	9	9	4.7	2.1	0.0
South Atlantic States							46.1	+0.5										71	2.39	-1.2										4.8		
Asheville	2,253	89	104	27.70	30.14	-.01	38.1	+2.7	64	30	48	14	16	28	38	32	27	70	1.84	-1.3	5	5,620	nw.	27	se.	5	14	10	7	4.3	2.6	0.0
Charlotte	779	55	62	29.24	30.10	-.05	42.4	+1.2	67	25	52	20	15	33	30	36	30	68	2.37	-1.6	7	3,351	sw.	23	sw.	5	12	6	13	5.1	2.0	0.0
Greensboro	886	5	56	29.11	30.10	----	37.3	----	66	25	49	3	16	26	41	31	27	79	1.51	----	6	4,789	sw.	26	sw.	5	13	5	13	5.1	5.0	0.0
Hatteras	11	5	50	30.05	30.06	-.08	46.0	-1.1	64	5	53	30	16	39	25	42	38	80	2.86	-1.6	9	9,005	w.	48	n.	14	15	6	10	4.6	0.0	0.0
Raleigh	376	103	146	29.67	30.09	-.04	43.4	+2.3	72	25	52	20	16	35	29	36	30	65	2.08	-1.6	6	5,248	sw.	30	nw.	6	15	5	11	4.8	4.0	0.0
Wilmington	78	81	91	30.04	30.12	-.02	47.0	+0.5	72	25	56	21	16	38	27	40	35	71	2.07	-1.2	8	3,914	w.	24	w.	6	14	9	8	4.6	T.	0.0
Charleston	48	11	92	30.07	30.12	-.03	49.0	-0.9	72	31	57	30	15	41	25	42	37	72	2.37	-0.6	9	5,934	w.	30	w.	14	14	7	10	5.0	0.0	0.0
Columbia, S. C.	351	41	57	29.73	30.13	-.02	46.2	+0.2	70	25	56	24	2	37	31	39	32	67	2.41	-1.0	6	4,281	w.	34	sw.	5	13	11	7	4.7	T.	0.0
Due West	711	10	55	29.34	30.14	----	42.8	----	68	31	53	19	15	33	31	----	----	----	2.25	----	7	5,924	w.	33	sw.	5	14	8	9	4.6	1.1	0.0
Greenville, S. C.	1,039	139	146	28.97	30.09	----	44.1	+3.8	67	31	53	24	15	35	29	38	32	70	2.55	-2.3	7	4,939	sw.	34	sw.	5	14	6	11	4.7	3.5	0.0
Augusta	182	62	77	29.92	30.12	-.04	46.5	-0.5	71	28	57	23	16	36	35	40	36	76	2.23	-1.7	6	3,297	nw.	27	sw.	5	13	10	8	4.7	T.	0.0
Savannah	65	150	194	30.05	30.12	-.03	50.8	-0.6	72	31	60	28	15	42	27	43	36	67	2.11	-0.7	8	8,010	w.	39	w.	14	13	6	12	5.3	0.0	0.0
Jacksonville	43	209	245	30.09	30.14	-.01	53.6	-1.8	74	28	62	29	15	45	25	46	41	71	3.36	+0.6	9	7,314	w.	37	w.	14	12	8	11	5.1	0.0	0.0
Florida Peninsula							62.3	-3.1										81	4.82	+2.4										6.4		
Key West	22	10	64	30.07	30.09	-.01	65.4	-4.1	81	19	70	48	15	60	17	61	60	86	3.98	+2.0	8	7,281	ne.	36	w.	5	8	10	13	6.4	0.0	0.0
Miami	25	124	168	30.08	30.11	-.03	63.8	-2.7	76	4	71	37	22	57	26	59	56	77	7.07	+4.6	10	7,575	n.	32	w.	6	1	9	21	7.8	0.0	0.0
Tampa	35	79	197	30.10	30.14	+.02	57.8	-2.6	75	27	67	32	15	49	26	52	48	79	3.42	+0.7	9	8,248	ne.	34	nw.	6	10	9	12	6.0	0.0	0.0
Titusville	44	5	----	30.09	30.14	----	57.5	----	79	12	67	32	15	48	29	----	----	----	3.40	----	6	----	nw.	----	----	----	8	15	8	5.6	0.0	0.0
East Gulf States							47.7	-0.4										71	3.31	-1.4										5.5		
Atlanta	1,173	190	216	28.86	30.13	-.02	43.4	+0.8	64	25	50	18	15	36	27	37	31	66	2.61	-2.3	10	7,436	nw.	32	nw.	14	12	3	16	5.9	0.1	0.0
Macon	370	78	87	29.74	30.15	-.01	45.8	-1.0	70	28	56	21	15	35	36	39	33	68	2.89	-1.3	8	3,791	nw.	24	sw.	5	12	6	13	5.7	T.	0.0
Thomasville	273	49	103	29.85	30.15	-.01	50.8	-0.2	73	31	60	25	15	41	32	43	38	71	3.12	-1.0	10	4,913	nw.	33	sw.	5	10	9	12	5.5	T.	0.0
Apalachicola	36	11	51	30.11	30.15	----	51.4	----	73	29	58	29	15	44	22	47	43	80	4.36	+0.7	8	5,491	nw.	25	nw.	5	12	7	12	5.1	0.0	0.0
Pensacola	56	149	185	30.11	30.17	+.03	51.0	-1.5	72	29	58	27	15	44	22	46	41	74	3.81	-0.2	6	8,060	e.	40	w.	4	8	11	12	5.7	0.0	0.0
Anniston	741	9	57	29.35	30.17	+.01	42.8	+0.6	67	25	53	18	15	32	37	----	----	----	2.49	-2.7	8	3,278	nw.	22	sw.	5	14	4	13	4.9	T.	0.0
Birmingham	700	11	48	29.38	30.17	+.01	45.4	+0.3	69	28	54	18	15	37	31	38	33	68	2.15	-3.4	9	4,363	nw.	28	se.	4	13	4	14	5.3	T.	0.0
Mobile	57	125	161	30.10	30.16	+.01	50.6	-0.9	74	29	59	27	15	42	31	45	41	77	5.43	+0.6	8	5,498	n.	34	sw.	4	9	12	10	5.2	0.0	0.0
Montgomery	223	100	112	29.92	30.18	+.02	47.6	-0.6	72	28	57	23	15	39	31	41	34	66	2.48	-2.7	8	3,731	nw.	22	nw.	14	10	9	12	5.4	T.	0.0
Corinth	469	6	----	----	----	----	42.6	----	69	25	53	14	15	32	37	----	----	----	2.31	----	7	----	se.	----	----	----	11	12	8	----	0.5	0.0
Meridian	375	87	95	29.76	30.17	+.01	46.2	-0.8	74	28	56	20	15	36	36	40	34	72	2.66	-2.7	5	3,097	ne.	27	sw.	5	12	7	12	5.2	0.0	0.0
Vicksburg	247	65	73	29.91	30.20	+.05	48.4	+0.2	72	29	56	23	15	40	26	42	35	68	3.04	-2.3	6	4,206	nw.	26	nw.	5	10	5	16	6.0	0.0	0.0
New Orleans	53	76	84	30.11	30.17	+.04	52.5	-1.7	72	28	59	30	15	46	22	47	41	71	4.65	+0.3	[illegible]	3,987	ne.	24	sw.	4	10	7	14	5.7	0.0	0.0
West Gulf States							50.4	+2.2										76	3.35	+0.6										5.8		
Shreveport	249	77	93	29.90	30.19	+.05	49.1	+2.1	71	29	57	24	14	41	28	44	41	79	3.58	-0.4	8	3,955	s.	22	w.	5	8	13	10	5.3	0.0	0.0
Bentonville	1,303	11	44	28.72	30.12	-.02	39.8	+5.7	70	30	49	8	14	30	34	----	----	----	0.61	----	7	3,009	nw.	17	nw.	12	21	1	9	----	0.3	0.0
Fort Smith	457	79	94	29.66	30.15	+.01	43.1	+3.6	70	30	53	16	14	34	35	38	32	72	0.48	-2.1	5	4,963	e.	32	w.	13	12	8	11	5.2	0.4	0.0
Little Rock	357	136	153	29.78	30.17	+.02	44.1	+2.7	74	30	52	20	14	36	34	38	31	64	1.00	-3.7	5	5,056	nw.	32	w.	13	10	9	12	5.3	T.	0.0
Austin	605	136	148	29.52	30.16	----	51.4	+1.9	75	31	60	28	14	43	34	47	43	79	4.30	+2.2	11	4,316	n.	28	nw.	4	8	5	18	6.3	0.0	0.0
Brownsville	57	83	100	30.06	30.12	----	60.0	+0.2	77	4	67	41	21	53	25	56	53	85	4.56	+3.1	14	6,075	e.	27	nw.	4	4	12	15	7.0	0.0	0.0
Corpus Christi	20	11	78	30.13	30.15	+.05	57.0	+1.0	75	4	63	39	21	51	26	53	50	83	2.29	+0.7	10	6,588	e.	30	nw.	4	4	10	17	6.9	0.0	0.0
Dallas	512	220	227	29.60	30.17	----	48.2	----	69	31	57	22	14	40	27	----	----	----	1.29	-1.1	8	6,893	w.	35	sw.	7	19	7	5	3.4	0.0	0.0
Fort Worth	670	106	114	29.43	30.16	+.04	49.9	+4.5	70	31	59	26	14	41	28	44	40	76	1.79	-0.3	8	4,498	sw.	22	nw.	5	12	7	12	5.5	0.0	0.0
Galveston	54	106	114	30.13	30.19	+.06	54.0	+0.2	71	31	59	37	14	49	20	50	47	81	5.58	+2.2	6	6,657	e.	32	nw.	11	6	11	14	6.4	0.0	0.0
Groesbeck	461	11	56	29.66	30.16	----	49.2	----	70	31	57	26	14	42	28	----	----	----	3.74	+1.0	8	5,732	n.	29	n.	13	9	10	12	5.6	0.0	0.0
Houston	138	292	314	30.03	30.18	----	53.8	+1.1	72	30	61	33	14	47	20	----	----	----	3.42	-0.3	8	7,748	se.	33	nw.	5	9	5	17	6.3	0.0	0.0
Palestine	510	61	72	29.63	30.17	+.05	50.2	+2.0	72	31	58	24	14	42	28	44	40	73	2.65	-0.8	7	4,434	s.	20	sw.	7	15	6	10	5.0	0.0	0.0
Port Arthur	34	58	66	30.13	30.17	----	53.4	----	72	31	60	34	14	46	25	----	----	----	6.34	+2.6	7	4,865	e.	24	nw.	5	9	7	15	6.4	0.0	0.0
San Antonio	693	242	301	29.41	30.14	+.04	52.6	+0.3	70	24	60	30	14	45	26	47	42	73	5.86	+4.4	9	7,436	ne.	40	w.	4	10	7	14	6.1	0.0	0.0
Taylor	571	38	51	29.57	30.19	+.08	50.2	+2.7	73	31	59	26	14	42	34	----	----	----	3.40	+1.5	10	4,260	n.	25	sw.	3	9	9	13	5.9	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with .01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
							36.6	+3.0										74	1.10	−2.6										6.2		
Chattanooga	762	190	215	29.32	30.15	−0.01	41.8	+0.6	66	24	50	17	15	33	32	36	30	68	2.72	−2.5	10	4,840	sw.	29	ne.	5	12	8	11	5.2	1.6	0.0
Knoxville	995	102	111	29.05	30.14	−.01	40.0	+1.2	64	25	49	12	16	31	29	35	30	73	1.79	−2.9	10	4,074	sw.	29	sw.	5	14	6	11	4.8	7.6	0.0
Memphis	399	76	97	29.72	30.16	.00	43.6	+2.7	69	30	50	15	14	37	25	38	32	68	0.98	−3.8	6	5,479	nw.	35	nw.	13	12	6	13	5.5	T.	0.0
Nashville	546	168	191	29.57	30.17	+.01	40.8	+2.2	69	30	49	14	15	32	37	36	30	70	1.31	−3.4	9	5,400	nw.	33	nw.	14	14	5	12	4.9	0.7	0.0
Lexington	989	193	230	29.05	30.15	+.02	35.6	+2.7	60	24	42	12	1	29	28	----	----	----	0.77	−3.4	6	8,616	sw.	33	w.	30	10	6	15	5.8	T.	0.0
Louisville	525	188	234	29.54	30.13	−.01	37.6	+3.2	64	25	44	15	1	31	28	34	30	77	0.96	−3.0	7	6,540	sw.	26	sw.	19	10	5	16	5.8	0.2	0.0
Evansville	431	76	116	29.66	30.14	.00	37.6	+4.1	66	30	45	15	1	30	32	33	29	74	0.62	−3.1	7	5,931	sw.	24	w.	30	10	9	12	5.7	0.8	0.0
Indianapolis	822	194	230	29.18	30.09	−.03	33.4	+5.0	61	24	40	9	1	27	24	30	26	77	0.54	−2.4	6	7,156	sw.	33	w.	30	8	9	14	6.2	1.5	0.0
Royal Center	736	11	55	29.24	30.07	------	30.8	------	56	24	38	4	1	24	25	----	----	----	0.77	−1.5	8	6,830	sw.	31	w.	20	7	9	15	6.5	2.7	0.0
Terre Haute	575	96	129	29.47	30.10	------	34.6	------	61	24	42	9	1	28	26	31	27	79	0.95	−1.8	4	5,730	s.	27	w.	20	9	5	17	6.0	1.9	0.0
Cincinnati	627	11	51	29.41	30.11	−.01	35.3	+5.0	64	25	42	11	1	28	27	31	27	77	0.97	−2.5	6	5,090	sw.	26	sw.	30	8	6	17	6.6	0.6	0.0
Columbus	822	216	230	29.18	30.08	−.03	33.0	+4.4	58	25	40	13	15	26	23	30	26	77	0.88	−2.2	8	7,457	sw.	34	w.	30	5	10	16	6.8	1.4	T.
Dayton	899	137	173	29.10	30.09	------	33.8	+4.3	59	24	40	10	1	28	22	30	26	78	0.97	−2.3	5	6,054	sw.	30	w.	30	6	6	19	7.2	2.0	0.0
Elkins	1,947	59	67	27.98	30.13	+.01	30.6	+0.2	59	25	41	−7	2	20	55	27	24	81	1.36	−2.4	16	4,362	w.	33	e.	5	2	6	23	8.0	9.0	0.0
Parkersburg	637	77	82	29.44	30.11	−.01	36.0	+3.5	65	25	44	14	2	28	32	31	26	73	0.91	−2.7	8	4,151	sw.	26	nw.	30	6	6	19	7.4	T.	0.0
Pittsburgh	842	353	410	29.14	30.07	−.04	33.2	+2.5	59	25	40	13	21	26	25	29	24	70	1.16	−1.9	13	7,682	w.	42	nw.	30	5	11	15	6.5	2.9	0.4
Lower Lake Region							27.1	+2.6										78	2.08	−0.5										7.0		
Buffalo	767	247	280	29.13	29.99	−.08	25.6	+1.0	45	25	31	7	15	20	27	24	21	82	2.99	−0.3	20	12,982	w.	52	w.	19	1	13	17	7.7	22.3	6.2
Canton	448	16	61	29.48	29.98	------	14.8	−1.5	39	3	24	−27	24	5	55	----	----	----	2.18	−0.3	13	6,040	sw.	30	e.	6	9	6	16	6.4	26.5	13.8
Ithaca	836	74	100	29.05	29.99	------	27.0	+2.7	50	27	34	6	22	20	28	23	19	76	1.64	−0.6	15	6,479	nw.	30	nw.	7	3	12	16	7.3	21.0	6.5
Oswego	335	71	85	29.61	30.00	−.07	24.1	+0.2	45	25	31	2	15	17	35	22	19	79	3.54	+0.6	17	7,323	s.	31	n.	31	1	3	27	8.8	41.9	18.8
Rochester	523	86	102	29.41	30.00	−.07	26.2	+1.6	49	25	32	9	24	21	37	24	19	75	2.91	0.0	21	6,548	w.	26	sw.	19	1	10	20	7.8	28.7	12.0
Syracuse	596	65	79	29.33	29.99	−.08	25.8	+2.8	46	25	32	5	15	20	35	----	----	----	2.70	−0.3	16	4,894	w.	22	nw.	29	5	8	18	7.5	18.5	9.2
Erie	714	130	166	29.22	30.02	−.06	28.8	+2.0	52	25	34	14	21	23	22	26	23	79	1.68	−1.1	16	9,854	sw.	33	sw.	19	8	7	16	6.4	10.8	T.
Cleveland	762	267	337	29.18	30.03	−.06	31.6	+5.1	56	25	38	13	21	25	23	28	23	72	1.47	−1.0	15	10,272	sw.	40	w.	31	5	11	15	6.9	3.8	T.
Sandusky	629	5	67	29.35	30.05	−.04	30.6	+4.3	55	25	38	7	15	24	21	----	----	----	1.73	−0.5	12	6,479	sw.	27	sw.	25	7	10	14	6.5	4.3	T.
Toledo	628	208	243	29.35	30.05	−.04	30.6	+4.8	53	25	37	10	21	24	23	27	23	75	1.73	−0.4	11	9,335	sw.	35	sw.	20	11	5	15	5.9	3.7	0.0
Fort Wayne	856	100	119	29.10	30.06	------	31.4	+4.5	54	24	38	10	15	25	21	28	25	80	0.67	−1.7	5	6,775	sw.	34	nw.	30	8	10	13	6.3	2.3	T.
Detroit	730	218	258	29.22	30.04	−.04	28.4	+4.0	49	25	34	10	21	23	22	27	25	87	1.68	−0.4	13	7,708	sw.	28	sw.	16	8	7	16	6.5	14.3	T.
Upper Lake Region							25.3	+6.4										83	1.26	−0.7										7.5		
Alpena	609	13	92	29.30	30.00	−.04	23.0	+3.9	41	26	30	3	21	16	24	21	18	82	1.29	−0.6	16	6,976	nw.	29	se.	24	1	9	21	8.1	15.4	4.4
Escanaba	612	54	60	29.30	29.99	−.06	22.4	+7.0	36	16	29	−3	21	16	25	21	18	82	0.83	−0.7	10	6,148	nw.	25	n.	28	4	8	19	7.4	13.3	7.0
Grand Haven	632	54	89	29.30	30.00	−.07	29.2	+4.9	45	24	34	10	21	24	21	28	26	86	2.39	0.0	13	7,872	sw.	31	w.	20	3	5	23	8.3	19.8	0.8
Grand Rapids	707	70	244	29.23	30.02	−.04	28.7	+4.2	46	25	34	7	21	23	19	27	24	81	1.80	−0.6	13	7,895	sw.	33	sw.	16	1	8	22	8.2	19.6	T.
Houghton	668	64	99	29.22	29.97	−.08	21.4	+6.7	38	26	28	−2	21	15	30	----	----	----	1.16	−1.3	14	5,567	e.	37	w.	25	1	3	27	9.2	11.9	5.3
Lansing	878	6	88	29.03	30.00	------	26.5	+4.1	44	25	33	4	21	20	22	25	24	94	1.34	−0.5	16	6,126	sw.	25	nw.	21	8	6	17	6.6	15.2	1.3
Ludington	637	60	66	29.27	29.99	------	29.2	+6.1	44	24	34	10	21	24	20	28	25	84	1.72	−0.4	14	7,405	w.	35	sw.	1	5	6	20	7.3	18.6	2.4
Marquette	734	77	111	29.15	29.97	−.07	23.6	+7.3	42	26	30	2	21	18	24	22	19	82	1.70	−0.6	18	6,429	w.	29	sw.	15	1	3	27	9.0	17.0	16.5
Port Huron	638	70	120	29.29	30.00	−.06	25.6	+3.3	45	25	32	0	15	19	27	24	22	84	1.99	+0.2	14	7,499	sw.	32	nw.	30	5	9	17	7.2	15.3	9.2
Sault Sainte Marie	614	11	52	29.28	30.01	−.02	18.4	+5.1	38	26	26	−15	21	11	29	17	15	86	0.82	−1.1	13	5,110	e.	33	nw.	25	6	6	19	7.1	9.4	9.4
Chicago	673	7	131	29.30	30.05	−.05	32.0	+8.3	52	24	38	6	21	26	23	28	24	75	0.57	−1.3	5	7,177	sw.	29	nw.	30	10	6	15	6.1	2.1	0.0
Green Bay	617	109	141	29.30	29.98	−.08	24.2	+8.5	39	16	31	−5	21	18	24	23	21	83	0.64	−0.9	7	6,661	sw.	27	sw.	16	3	6	22	8.2	7.9	1.9
Milwaukee	681	125	221	29.25	30.01	−.07	29.6	+9.0	47	24	36	1	21	24	25	27	24	78	1.04	−0.7	7	8,827	w.	31	nw.	30	9	3	19	6.6	10.1	T.
Duluth	1,133	5	47	28.73	30.00	−.09	19.8	+11.9	39	26	27	−11	21	12	29	18	16	85	0.29	−0.7	6	7,991	nw.	38	nw.	24	11	4	16	6.3	4.3	T.
North Dakota							21.4	+16.4										86	0.08	−0.4										5.6		
Moorhead	940	50	58	28.96	30.02	−.12	19.6	+15.8	52	29	28	−15	14	11	31	18	16	89	0.07	−0.6	4	5,587	s.	23	nw.	20	5	7	19	7.4	0.9	T.
Bismarck	1,674	8	57	28.17	30.03	−.10	24.6	+16.8	59	29	35	−9	13	14	30	22	18	80	0.05	−0.4	4	4,929	nw.	26	n.	12	18	4	9	4.1	0.6	T.
Devils Lake	1,478	11	44	28.36	30.00	−.12	16.6	+14.8	43	29	26	−14	14	8	35	16	15	94	0.19	−0.3	5	5,967	nw.	29	n.	20	4	7	20	7.2	2.9	1.5
Ellendale	1,457	10	56	28.39	30.01	------	23.8	------	53	29	34	−12	14	14	37	----	----	----	0.05	−0.4	2	8,483	nw.	35	nw.	12	6	13	12	6.3	0.1	T.
Grand Forks	833	12	67	------	------	------	16.2	------	41	29	25	−14	14	8	30	15	----	----	0.14	------	4	------	nw.	32	s.	14	9	13	9	----	1.4	2.2
Williston	1,878	41	48	27.97	30.02	−.09	24.6	+18.2	54	31	34	−13	13	15	33	22	19	81	0.06	−0.5	3	4,289	w.	31	w.	15	19	8	4	3.0	0.5	0.0
Upper Mississippi Valley							30.9	+9.4										79	0.59	−1.0										5.8		
Minneapolis	918	102	208	28.98	29.99	------	25.8	+13.1	52	26	33	−5	14	19	27	----	----	----	0.13	−0.7	4	7,291	nw.	28	nw.	20	5	11	15	6.5	0.9	0.0
St. Paul	837	236	261	29.06	30.00	−.11	25.3	+12.7	49	26	33	−4	14	18	29	----	----	----	0.13	−0.8	3	6,995	nw.	29	nw.	30	7	8	16	6.5	1.1	0.0
La Crosse	714	11	48	29.22	30.01	−.10	26.4	+10.3	48	28	34	−5	21	19	32	24	22	84	0.70	−0.4	6	3,482	s.	15	s.	26	7	6	18	6.9	8.4	T.
Madison	974	70	78	28.93	30.03	−.07	26.1	+9.4	45	24	32	−3	21	20	27	25	22	85	0.78	−0.6	6	5,550	w.	23	s.	15	7	6	18	6.6	12.4	T.
Wausau	1,247	4	62	------	30.00	------	22.3	------	39	30	29	−6	21	16	23	----	----	----	0.84	−0.4	7	3,885	w.	16	nw.	30	5	10	16	----	13.3	0.5
Charles City	1,015	10	51	28.94	30.06	−.08	25.5	+11.8	51	28	34	−7	21	17	37	23	20	84	0.65	−0.4	1	4,213	nw.	17	sw.	15	12	8	11	5.0	6.5	0.0
Davenport	606	71	79	29.38	30.07	−.05	31.4	+9.6	55	24	38	5	21	24	29	28	24	78	0.58	−0.8	3	6,907	sw.	31	nw.	30	12	8	11	5.4	4.3	0.0
Des Moines	861	5	99	29.14	30.08	−.06	30.3	+10.2	56	29	40	0	14	21	35	27	23	78	0.57	−0.5	3	6,426	nw.	28	s.	1	9	10	12	5.4	8.6	T.
Dubuque	700	81	96	29.26	30.05	−.07	28.6	+9.5	49	24	35	−2	21	22	29	36	24	84	0.79	−0.5	4	3,834	nw.	21	nw.	30	12	4	15	6.0	7.9	T.
Keokuk	614	64	78	29.41	30.11	−.03	33.9	+9.0	64	24	42	6	14	25	30	29	24	72	0.54	−1.0	3	5,181	sw.	22	sw.	2	11	13	7	4.8	1.2	0.0
Cairo	358	87	93	29.75	30.15	−.01	39.0	+4.1	73	30	47	9	15	31	36	34	29	72	1.77	−2.0	7	5,178	s.	29	nw.	13	11	6	14	5.7	7.3	0.0
Peoria	609	11	45	29.41	30.10	−.02	32.6	+9.5	61	24	40	6	1	25	29	28	25	82	0.48	−1.3	5	4,661	s.	21	w.	20	12	8	11	5.0	1.2	0.0
Springfield, Ill	636	5	191	29.40	30.10	−.03	34.4	+7.9	64	24	42	9	1	27	28	30	26	76	0.27	−1.8	3	8,469	s.	31	w.	20	7	10	14	6.5	0.4	0.0
Hannibal	534	74	109	29.52	30.12	−.01	35.1	+8.0	65	24	43	6	14	27	29	----	----	----	0.24	−1.5	4	5,977	sw.	25	sw.	2	9	13	9	5.4	0.6	0.0
St. Louis	568	265	303	29.49	30.12	−.02	37.8	+7.0	70	24	46	9	14	30	27	33	27	70	0.40	−1.9	4	8,242	sw.	27	sw.	2	11	11	9	5.1	1.5	0.0
Missouri Valley							33.9	+11.1										71	0.41	−0.6										4.0		
Columbia, Mo	784	6	84	29.26	30.12	−.01	36.1	+6.9	66	24	44	5	14	28	30	----	----	----	0.28	−1.6	4	5,383	sw.	22	sw.	20	13	5	13	5.5	0.4	0.0
Kansas City	963	161	181	29.06	30.13	−.02	38.2	+10.0	64	24	46	7	14	30	27	33	28	70	0.56	−0.6	4	6,838	s.	26	nw.	5	14	10	7	4.3	0.2	0.0
St. Joseph	967	11	49	29.04	30.11	------	35.8	------	65	24	45	4	14	26	29	30	26	73	0.53	−0.5	3	5,385	nw.	30	nw.	12	21	6	4	3.2	0.3	0.0
Springfield, Mo	1,324	98	104	28.70	30.14	.00	38.1	+4.6	64	24	46	5	14	30	29	33	28	73	0.63	−1.7	8	6,603	s.	25	nw.	13	19	3	9	3.6	1.2	0.0
Iola	984	11	50	29.05	30.14	.00	37.8	+8.0	69	30	47	8	14	28	36	----	----	----	1.06	−0.3	6	3,831	s.	18	nw.	13	13	8	10	5.2	0.2	0.0
Topeka	987	92	107	------	------	------	37.2	+9.6	66	30	47	6	14	23	33	----	----	----	0.55	−0.4	3	5,937	sw.	28	nw.	13	16	9	6	3.6	0.7	0.0
Lincoln	1,189	11	81	28.80	30.11	−.04	34.0	+11.2	66	29	45	2	14	23	37	28	23	71	0.19	−0.4	3	5,886	s.	29	nw.	19	13	13	5	4.4	1.9	0.0
Omaha	1,105	115	122	28.88	30.10	−.05	33.8	+11.9	63	29	43	1	14	24	30	28	22	67	0.38	−0.3	4	4,984	nw.	24	nw.	13	18	7	6	3.3	4.3	0.0
Valentine	2,598	47	54	27.31	30.12	.00	30.4	+11.5	63	29	42	−7	14	19	36	25	20	73	0.33	−0.2	3	5,005	w.	24	nw.	19	17	10	4	3.6	4.2	T.
Sioux City	1,135	94	164	28.84	30.10	−.05	31.2	+13.4	63	29	41	−3	14	22	36	26	22	73	0.40	−0.3	5	7,416	nw.	31	nw.	20	15	7	9	4.4	4.2	0.0
Huron	1,306	59	74	28.62	30.07	−.09	27.8	+16.5	63	29	40	−10	14	15	39	23	18	71	0.12	−0.4	4	5,668	w.	28	nw.	19	15	11	5	3.9	1.4	0.0
Pierre	1,572	70	75	28.35	30.06	−.07	30.6	+14.6	66	29	41	−2	14	20	34	26	20	68	0.24	−0.2	3	4,552	nw.	26	nw.	12	16	13	2	3.3	2.7	0.0
Yankton	1,233	49	57	28.72	30.08	−.08	31.9	+14.6	66	29	43	−2	14	21	37	----	----	----	0.05	−0.5	1	4,918	w.	22	nw.	13	15	10	6	4.0	0.5	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°	°F.	°F.	°F.		In.	In.		Miles								0-10	In.	In.
Northern Slope							29.4	+10.1										68	0.20	-0.6										5.0		
Billings	3,140	5	----	------	------	------	32.6	------	68	29	47	-1	18	18	45	----	----	----	0.14	------	1	------	nw.	----	------	----	12	12	7	----	2.0	----
Havre	2,505	11	44	27.34	30.05	-0.05	28.6	+15.7	57	23	39	-4	13	19	39	25	21	75	0.57	-0.2	3	7,287	sw.	32	sw.	25	9	13	9	5.0	5.0	0.0
Helena	4,124	89	113	25.82	30.13	-.02	31.8	+11.6	56	28	40	12	20	24	26	27	21	63	0.04	-0.8	3	4,447	sw.	34	sw.	28	3	8	20	7.4	0.5	0.0
Kalispell	2,973	48	56	27.02	30.17	+.05	27.8	+7.4	52	23	34	8	20	22	21	27	25	86	0.55	-1.0	10	2,251	nw.	17	w.	23	2	5	24	8.5	4.6	3.0
Miles City	2,371	48	55	27.49	30.12	.00	31.0	+16.5	66	29	43	-9	13	19	38	26	20	70	0.05	-0.6	1	3,405	s.	27	nw.	24	17	8	6	4.1	0.7	0.0
Rapid City	3,259	50	58	26.61	30.13	+.03	34.2	+12.2	70	29	46	-3	13	23	42	27	18	57	0.15	-0.3	4	4,819	w.	32	n.	26	14	12	5	3.8	2.0	0.0
Cheyenne	6,088	84	101	23.99	30.13	+.08	30.8	+5.3	59	29	41	6	9	21	35	23	13	51	0.16	-0.3	3	9,335	w.	37	sw.	26	14	13	4	3.9	1.8	T.
Lander	5,372	60	68	24.67	30.23	+.11	24.8	+6.5	60	28	38	0	10	11	37	19	14	74	T.	-0.6	0	2,147	sw.	20	sw.	16	14	13	4	3.7	T.	0.0
Sheridan	3,790	10	47	26.10	30.13	------	29.2	------	71	29	43	2	14	15	47	24	17	66	0.33	-0.5	6	2,257	nw.	28	nw.	26	10	13	8	5.0	6.0	0.0
Yellowstone Park	6,241	11	48	------	30.29	+.15	22.8	+5.2	45	28	31	5	20	15	29	----	----	72	0.11	-1.5	8	5,176	sw.	27	sw.	1	3	10	18	----	3.6	9.1
North Platte	2,821	11	51	27.11	30.13	+.01	33.3	+10.4	63	29	46	2	14	21	37	26	21	71	0.03	-0.4	3	3,972	w.	23	nw.	19	18	9	4	3.4	0.3	0.0
Middle slope							37.3	+6.8										64	0.27	-0.5										4.1		
Denver	5,292	106	113	24.74	30.13	+.08	35.8	+6.0	64	29	47	14	10	25	38	27	16	50	0.02	-0.4	1	4,454	s.	18	w.	1	17	10	4	3.6	0.1	0.0
Pueblo	4,685	80	86	25.32	30.14	+.09	32.4	+2.5	64	23	49	4	19	16	52	25	16	55	0.12	-0.2	1	3,424	nw.	25	w.	1	17	11	3	3.6	1.6	0.0
Concordia	1,392	50	58	28.63	30.15	+.01	35.9	+9.5	69	29	47	4	14	24	39	29	24	71	0.10	-0.5	2	4,629	nw.	25	nw.	19	15	12	4	3.5	0.2	0.0
Dodge City	2,509	11	51	27.49	30.17	+.06	37.5	+8.5	71	24	50	10	14	24	41	30	24	70	0.10	-0.3	3	5,052	nw.	22	nw.	18	18	8	5	3.4	0.4	0.0
Wichita	1,358	139	158	28.66	30.13	.00	39.0	+7.7	68	30	48	8	14	30	32	34	28	71	0.29	-0.5	4	6,821	s.	34	s.	24	16	8	7	4.1	0.1	0.0
Broken Arrow	765	11	56	29.31	30.15	------	41.4	------	73	30	51	13	14	32	33	----	----	----	0.57	-1.4	6	7,205	s.	33	nw.	13	11	10	10	5.2	T.	0.0
Oklahoma City	1,214	10	47	28.83	30.15	+.04	43.0	+6.6	73	30	53	15	14	33	34	36	31	70	0.70	-0.5	6	5,486	s.	23	s.	24	11	12	8	5.3	0.2	0.0
Southern Slope							44.4	+1.7										70	1.67	+1.0										5.2		
Abilene	1,738	10	52	28.31	30.16	+.07	46.4	+2.2	68	31	56	22	14	37	32	41	36	74	1.82	+0.9	9	5,198	s.	26	w.	7	8	8	15	6.1	0.0	0.0
Amarillo	3,676	10	49	26.32	30.13	+.07	40.0	+4.7	66	24	51	20	13	29	33	32	25	62	0.31	-0.2	1	5,317	sw.	22	se.	6	16	11	4	3.8	0.1	0.0
Del Rio	944	64	71	29.11	30.12	+.06	51.4	-0.9	71	7	59	31	21	43	34	47	43	79	4.12	+3.6	11	4,365	se.	44	nw.	4	8	11	12	5.9	0.0	0.0
Roswell	3,566	75	85	26.45	30.14	+.10	40.0	+0.8	65	31	52	18	1	28	39	34	27	66	0.42	-0.1	3	3,709	s.	35	w.	6	13	9	9	4.8	0.2	0.0
Southern Plateau							42.1	+1.4										50	0.34	-0.3										3.2		
El Paso	3,778	152	175	26.26	30.12	+.11	44.0	-1.0	66	24	55	23	19	33	33	36	25	53	0.83	+0.4	4	4,838	nw.	49	w.	6	17	7	7	3.6	0.0	0.0
Santa Fe	7,013	38	53	23.25	30.18	+.14	29.9	+1.1	56	28	42	7	20	18	35	22	12	53	0.25	-0.4	4	3,578	ne.	19	sw.	6	14	14	3	3.8	2.5	T.
Flagstaff	6,907	10	59	23.36	30.10	+.05	28.6	+1.9	54	28	44	-1	18	13	47	23	----	65	0.47	------	3	4,275	e.	25	e.	25	12	15	4	----	1.5	T.
Phoenix	1,108	10	107	28.88	30.05	+.02	52.9	+1.7	80	29	68	29	7	38	40	41	27	42	0.02	-0.8	2	2,915	e.	15	ne.	25	19	4	8	3.5	0.0	0.0
Yuma	141	9	54	29.92	30.07	+.02	55.6	+1.2	81	29	69	33	1	42	40	43	28	37	0.04	-0.4	2	3,782	n.	23	n.	18	23	6	2	1.9	0.0	0.0
Independence	3,957	6	27	26.07	30.16	+.09	41.4	+3.2	72	28	55	16	19	27	46	31	----	----	0.55	-0.4	5	------	nw.	----	------	----	25	2	4	----	T.	0.0
Middle Plateau							28.4	+0.2										71	0.43	-0.6										4.9		
Reno	4,532	74	81	25.55	30.20	+.07	34.8	+2.3	61	29	46	15	10	24	36	30	24	67	0.68	-0.9	4	2,162	w.	26	w.	23	12	8	11	5.0	3.8	0.0
Tonopah	6,090	12	20	------	------	------	34.5	------	57	29	42	18	10	27	23	28	21	58	0.17	------	3	------	se.	----	------	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.73	30.23	+.07	31.4	+2.8	61	29	45	5	10	17	41	27	21	70	0.09	-0.9	4	4,407	ne.	23	sw.	2	15	8	8	4.4	0.8	0.0
Modena	5,473	10	43	24.70	30.23	+.13	23.9	-2.8	47	16	37	-2	4	10	38	21	17	81	0.57	-0.3	5	4,144	w.	22	nw.	23	14	9	8	4.6	6.8	2.6
Salt Lake City	4,360	163	203	25.78	30.30	+.15	24.1	-5.1	41	2	31	9	22	17	24	23	20	82	0.72	-0.6	8	2,498	nw.	21	nw.	16	9	10	12	5.7	9.7	9.5
Grand Junction	4,602	60	68	25.52	30.22	+.16	27.6	+3.6	57	28	40	3	7	15	37	22	15	66	0.10	-0.5	2	2,844	se.	15	se.	8	12	12	7	4.7	1.2	0.0
Northern Plateau							32.0	+3.5										84	1.10	-0.5										7.8		
Baker	3,471	48	53	26.58	30.28	+.12	26.4	+1.5	45	29	33	1	8	20	25	25	22	84	1.05	-0.3	14	3,533	se.	18	se.	23	5	5	21	7.5	9.5	0.3
Boise	2,739	79	87	27.37	30.32	+.13	30.2	+0.4	48	23	37	11	8	23	28	28	26	84	0.88	-0.8	9	2,170	se.	18	se.	25	6	5	20	7.1	5.6	0.0
Lewiston	757	40	48	29.35	30.18	+.02	38.5	+6.0	57	28	45	18	8	32	24	----	----	----	1.00	-0.5	9	2,675	e.	17	se.	25	7	6	18	7.1	0.1	0.0
Pocatello	4,477	60	68	25.62	30.33	+.13	22.8	-1.9	45	23	32	3	8	14	28	21	18	80	0.52	-0.9	7	4,784	se.	29	s.	3	7	7	17	6.4	7.0	0.5
Spokane	1,929	101	110	28.07	30.18	+.06	34.4	+6.9	58	28	39	21	21	30	21	33	30	86	1.50	-0.7	13	2,864	s.	18	s.	23	0	3	28	9.2	5.8	0.0
Walla Walla	991	57	65	29.07	30.17	+.02	38.4	+5.7	63	27	44	20	1	33	30	36	33	83	1.51	-0.4	15	2,975	s.	24	se.	22	2	3	26	9.1	0.7	0.0
Yakima	1,076	58	67	28.99	30.17	------	33.0	+5.6	59	28	38	17	7	28	25	31	29	87	1.24	0.0	12	1,568	w.	19	sw.	23	2	5	24	8.3	9.0	0.0
North Pacific Coast Region							45.7	+5.4										83	6.33	0.0										8.4		
North Head	211	11	56	29.77	30.00	-.06	47.6	+5.5	67	29	52	38	1	43	21	45	43	85	7.95	-0.8	21	12,630	se.	62	s.	22	5	3	23	8.1	0.0	0.0
Port Angeles	29	8	53	------	30.01	------	42.8	------	51	2	47	33	19	39	13	----	----	----	3.77	-0.8	21	2,834	s.	22	sw.	14	0	5	26	----	0.0	0.0
Seattle	125	215	250	29.88	30.02	-.03	45.7	+6.2	67	28	50	31	19	41	20	43	40	81	6.34	+1.4	22	5,236	s.	37	sw.	14	3	6	22	7.9	0.0	0.0
Tacoma	194	172	201	29.82	30.03	-.01	44.6	+5.8	64	22	50	30	19	40	22	----	----	----	6.13	0.0	18	4,375	s.	34	s.	22	2	4	25	8.5	0.0	0.0
Tatoosh Island	86	9	53	29.84	29.94	-.04	47.0	+5.8	57	29	50	39	15	44	12	45	44	91	17.39	+5.6	26	13,740	e.	67	s.	22	0	5	26	9.1	0.0	0.0
Medford	1,329	29	58	28.68	30.13	------	39.3	------	61	22	48	22	19	30	32	37	34	83	1.39	-1.4	14	------	s.	39	se.	4	1	8	22	8.6	0.0	0.0
Portland, Oreg.	153	68	106	29.90	30.07	-.01	44.7	+5.3	64	27	50	30	9	40	19	41	38	79	4.30	-2.3	16	3,883	se.	30	s.	5	1	6	24	8.3	0.0	0.0
Roseburg	510	75	99	29.53	30.09	-.01	44.8	+3.6	66	27	52	31	10	37	26	42	39	81	3.38	-1.9	13	2,542	s.	27	sw.	15	2	6	23	8.0	0.0	0.0
Middle Pacific Coast Region							49.3	+2.0										80	4.37	-0.2										5.8		
Eureka	62	73	89	30.04	30.11	+.01	49.8	+2.9	64	22	57	34	17	42	25	48	45	83	4.09	-3.0	15	4,196	se.	30	se.	4	6	8	17	6.7	0.0	0.0
Red Bluff	330	5	58	29.78	30.14	+.02	47.2	+1.4	75	30	56	31	19	38	35	43	38	74	6.20	+1.4	12	3,436	nw.	26	se.	1	10	6	15	6.0	0.0	0.0
Sacramento	69	106	117	30.06	30.13	+.01	47.4	+1.6	62	26	55	31	12	40	25	46	44	86	2.50	-1.2	8	3,998	se.	22	se.	7	10	8	13	5.5	0.0	0.0
San Francisco	155	208	243	29.94	30.12	+.01	52.3	+2.4	68	29	58	43	10	47	20	48	45	77	5.50	+1.0	11	3,479	se.	18	se.	7	9	8	14	5.7	0.0	0.0
San Jose	141	12	110	29.98	30.14	------	49.8	+1.5	73	29	60	31	18	40	33	----	----	----	3.56	+0.6	11	3,467	se.	23	se.	1	12	6	13	5.3	0.0	0.0
South Pacific Coast Region							55.6	+3.9										66	3.41	+1.1										4.8		
Fresno	327	89	98	29.78	30.15	+.05	48.8	+2.6	66	28	57	31	19	40	29	45	42	79	2.61	+0.9	9	2,830	e.	21	se.	7	8	9	14	6.2	0.0	0.0
Los Angeles	338	159	191	29.71	30.08	.00	60.2	+5.6	85	29	69	46	9	51	27	49	38	52	3.90	+0.8	8	3,416	ne.	18	nw.	6	18	5	8	3.7	0.0	0.0
San Diego	87	62	70	29.97	30.07	.00	57.7	+3.4	81	28	66	44	17	49	27	51	45	67	3.72	+1.7	7	3,002	nw	25	w.	5	13	11	7	4.5	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.91	30.00	------	76.0	+1.0	88	21	81	68	7	71	18	----	----	----	1.67	-2.5	12	6,989	e.	32	n.	26	12	19	0	4.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	------	[2]29.84	+.01	80.6	+0.7	91	11	89	69	9	72	21	----	----	[1]76	T.	-0.8	0	7,259	n.	27	n.	22	13	18	0	4.2	0.0	0.0
Cristobal	36	6	97	[2]29.83	[2]29.86	-.01	82.0	+0.5	87	5	86	74	5	78	13	75	72	[1]75	2.01	-1.5	14	10,397	n.	30	nw.	22	6	25	0	4.9	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]28.97	[2]29.52	------	-0.8	------	36	18	10	-30	26	-11	47	-1	-5	76	0.26	------	4	1,206	n.	13	nw.	19	7	7	17	6.5	3.9	9.8
Juneau	80	11	50	[2]29.53	[2]29.62	------	37.6	------	52	31	42	25	23	34	17	36	34	86	9.14	------	28	6,114	se.	31	e.	3	0	0	31	9.7	2.6	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.03	[2]30.07	------	72.3	+1.4	80	8	77	62	20	68	13	66	64	77	0.45	-3.3	11	5,352	e.	24	ne.	18	16	12	3	3.9	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, January, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F*.	°*F*.	°*F*.	°*F*.	°*F*.	°*F*.	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				29.9		36.5	23.4	44	7	8.06		2.0
Sydney, C. B. I	48	29.73	29.78	−0.15	25.3	+4.8	32.6	17.9	48	−2	7.13	+2.03	31.9
Halifax, N. S	88	29.70	29.81	−.16	24.7	+2.9	32.9	16.5	52	−5	5.82	+0.05	13.2
Yarmouth, N. S	65	29.73	29.80	−.20	28.6	+2.3	34.7	22.6	48	7	5.18	+0.02	12.0
Charlottetown, P. E. I	38	29.69	29.73	−.23	19.6	+2.6	27.1	12.0	46	−6	4.92	+0.96	41.5
Chatham, N. B	28	29.69	29.73	−.24	11.4	+1.6	22.5	0.3	34	−22	2.44	−1.15	24.0
Father Point, Que	20	29.84	29.87	−.11	10.6	+2.6	17.1	4.2	26	−10	2.50	−0.35	25.0
Quebec, Que	296	29.60	29.94	−.08	11.4	+2.3	18.4	4.4	32	−14	3.51	−0.50	35.1
Doucet, Que	1,236				−3.2		9.7	−16.2	28	−46	1.22		12.2
Montreal, Que	187	29.73	29.96	−.08	14.4	+2.7	20.9	8.0	38	−8	3.20	−0.53	31.8
Ottawa, Ont	236	29.70	29.98	−.05	12.9	+3.3	21.2	4.6	38	−20	2.08	−0.91	20.5
Kingston, Ont	285	29.65	29.99	−.06	20.4	+3.3	28.0	12.9	38	−10	1.40	−2.05	14.C
Toronto, Ont	379												
Cochrane, Ont	930				1.1		10.2	−8.0	27	−36	1.58		
White River, Ont	1,244	29.58	29.97	−.04	5.5	+5.9	18.8	−7.7	32	−35	1.59	−0.10	
London, Ont	808				23.8		30.1	17.6	43	2	3.18		26.C
Southampton, Ont	656	29.24	29.98	−.05	22.5	+2.1	29.4	15.7	40	0	2.70	−1.35	27.0
Parry Sound, Ont	688	29.26	29.99	−.02	16.3	+2.5	23.9	8.7	36	−19	3.89	−0.19	38.9
Port Arthur, Ont	644	29.25	29.98	−.09	15.1	+12.0	23.3	6.8	34	−20	1.29	+0.47	12.9
Winnipeg, Man	760	29.13	30.00	−.11	9.9	+16.7	17.2	2.7	39	−13	0.26	−0.62	2.6
Minnedosa, Man	1,690	28.09	29.99	−.11	13.0	+20.2	21.0	4.9	40	−15	0.25	−0.55	2.5
Le Pas, Man	860				5.7		14.5	−3.1	34	−28	1.50		15.0
Qu'Appelle, Sask	2,115	27.60	29.92	−.16	18.2	+22.0	27.3	9.1	50	−25	0.44	−0.06	4.4
Moose Jaw, Sask	1,759				25.5		37.7	13.3	57	−15	0.09		0.4
Swift Current, Sask	2,392	27.31	29.90	−.19	26.9	+23.8	38.0	15.7	58	−12	0.10	−0.54	0.8
Medicine Hat, Alb	2,144	27.44	29.73	−.34	32.7	+27.2	43.1	22.2	66	−2	0.06	−0.51	0.6
Calgary, Alb	3,428	26.29	29.94	−.09	31.1	+22.7	41.9	20.4	60	3	0.05	−0.48	0.5
Banff, Alb	4,521	25.30	30.01	+.01	25.1	+13.0	32.1	18.1	51	−1	0.60	−0.59	5.3
Prince Albert, Sask	1,450	28.34	29.99	−.10	12.2	+20.6	20.7	3.8	50	−20	0.69	−0.28	6.9
Battleford, Sask	1,592	28.18	29.99	−.09	15.5	+21.4	25.6	5.3	48	−6	T.	−0.40	T.
Edmonton, Alb	2,150	27.50	29.84	−.19	22.3		30.6	14.0	55	−10	T.		T.
Kamloops, B. C	1,262												
Victoria, B. C	230	29.73	29.99	+.02	44.3	+5.8	47.0	41.6	56	37	4.66	−0.73	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

LATE REPORTS, DECEMBER, 1930

Stations	Altitude	Station reduced	Sea level reduced	Departure from normal	Mean max.+ mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Doucet, Que	1,236				11.2		20.0	2.4	34	−32	1.15		11.5
Montreal, Que	187	29.80	30.02	−.01	22.9	+4.6	28.7	17.1	40	−6	1.45	−2.20	12.5
Ottawa, Ont	236	29.76	30.05	+.03	22.3	+5.3	29.2	15.5	40	−10	1.88	−1.03	17.9
London, Ont	808				26.6		31.8	21.4	47	0	3.55		24.5
Southampton, Ont	656	29.28	30.01	−.01	27.0	+0.3	32.3	21.6	42	1	2.29	−1.69	19.2
Medicine Hat, Alb	2,144	27.52	29.82	−.15	31.7	+13.5	41.2	22.2	56	10	0.38	−0.17	1.8
Calgary, Alb	3,428	26.37	30.03	+.09	31.7	+13.5	42.8	20.7	58	10	0.52	−0.07	5.0
Banff, Alb	4,521	25.41	30.16	+.22	24.0	+4.9	30.5	17.5	39	4	T.	−1.21	T.
Edmonton, Alb	2,150	27.57	29.91	−.02	26.0	+12.9	34.1	18.0	41	4	0.32	−0.38	0.7
Kamloops, B. C	1,262	28.91	30.24	+.30	31.7	+2.8	35.8	27.6	43	18	0.34	−0.44	2.6
Estevan Point, B. C	20				44.4		48.9	40.0	54	30	15.74		0.0
Prince Rupert, B. C	170				43.2		46.5	40.0	53	33	15.48		0.0

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A PRELIMINARY METEOROLOGICAL SURVEY FOR AIRSHIP BASES ON THE MIDDLE ATLANTIC SEABOARD

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Location of a base for an airship terminal is analogous to the selection of proper docking facilities for ocean-going vessels. In addition to the usual docks required at any location, a natural harbor is always selected. These harbors, provided by nature, are visible, tangible things whose suitability may be quickly judged. In the case of aircraft, we maintain that there exist similar natural air harbors, however invisible and intangible. By meteorological and climatological analyses the location of these natural air harbors may be ascertained.

For a preliminary and general survey of the Atlantic coastal plain, we were fortunate in having the cooperation of the United States Weather Bureau and the Meteorological Services of the Army and the Navy. It is the purpose of this preliminary study to coordinate the data furnished by the above mentioned services in such a form as to isolate in a general way the desirable area from the undesirable on the middle Atlantic seaboard. Further examination is being made of wind conditions on possible sites in the area found generally favorable.

In a letter of May 8, 1930, the United States Weather Bureau issued detailed instructions for the compilation of the fundamental records used in this study. With the exception of the precipitation, temperature, and thunderstorm data, taken from the Atlas of American Agriculture, all data used in the study originated from the instructions of this letter.

In the selection of an airship base it is obvious that certain weather characteristics must have an important bearing. In this study particular emphasis has been placed on the following characteristics: Fog, snow, rain, thunderstorms, temperature, and winds. These factors influence the buoyancy of the ship, the ease of operation in flight, and handling on the ground.

Data pertinent to our conclusions are presented in complete detail in Appendix A of this report, copies of which are on file at the offices of the International Zeppelin Transport Corporation; the Pacific Zeppelin Transport Co. (Ltd.), in New York City; the Goodyear Zeppelin Corporation at Akron, Ohio; the United States Weather Bureau; the Aerological Office; United States Naval Air Station, Lakehurst, N. J.; and the offices of the heads of the Army and Navy Meteorological Services at Washington, D. C.

The following charts are taken from the above-mentioned Appendix A and are indicative of conditions exhibited by other charts in the same study, and presented as representative charts applicable to this study.

The following paragraphs discuss briefly weather conditions affecting the desirability of areas under consideration for airship bases.

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Temperatures.—The lifting characteristics of airships are dependent on temperature. With increased temperature in the summer time, the outside air density decreases and the ship loses in lift for a given volume. Low temperatures are to be avoided in the winter months even though they are productive of increased lifting power of the airship, for the reason that low temperatures are frequently accompanied by snow and glaze storms. In addition, labor necessary for the maintenance of airships becomes inefficient at low temperatures. The lines on Chart 6 show the average daily temperature in summer. It will be noted that an increase in temperature occurs to the south of Washington. Due to the resulting loss of buoyancy in the summer time, the area to the north of Washington or perhaps Richmond would be desirable. For winter operating conditions (charts for which closely parallel Chart 6, but with an approximate reduction of 40°) the desirable area would be south of the line between Trenton and Harrisburg.

Temperature range.—Fluctuations in temperature cause the lifting gas of an airship to expand and contract. The maximum volume of an airship, of course, is fixed, and the lifting power is, therefore, limited by the maximum temperature. Large fluctuations in temperatures exercise a harmful influence on buoyancy and economy of operation; therefore, small fluctuations of temperature are desirable at an airship terminal. Such fluctuations in temperature are shown on Chart 8 for the summer months, exhibiting a maximum fluctuation in southwestern Pennsylvania. From this chart the desirability of close proximity to the seacoast is apparent. However, it will be shown later that wind conditions do not permit such close proximity to the coast, and, therefore, the desirable area should probably include Philadelphia, Baltimore, and Richmond. For daily fluctuations of temperature in the winter, Chart 9 is presented. Here again the desirability of staying close to the Atlantic seaboard is apparent, and also it is possible to obtain a very small fluctuation of temperature in the vicinity of Philadelphia, Baltimore, and Richmond. The stabilizing influence of the Atlantic Ocean is apparent on both charts.

Thunderstorms.—It is popularly believed that the hazards to aircraft from thunderstorms are dependent entirely on lightning. Recently, studies and flight experience indicate that the real hazards of flying in the vicinity of thunderstorms are the tubulence or whirlpools in the air and the squalls which accompany such phenomena. The desirability of avoiding such storms is apparent. For the study of thunderstorms the number of days per year with such storms is presented on Chart 10. It will be noted that a fairly constant increase in the number of

thunderstorms per year occurs from Trenton southwest to the Gulf States, where a maximum occurs. A reasonable area from a thunderstorm viewpoint is the Trenton Richmond area, in which 32 to 40 thunderstorms occur per annum.

Snow.—Snow influences the operation of an aircraft in two respects. On an airship moored to a mast the snow has a tendency to accumulate on the upper surface and add appreciable weight to the ship. This can be avoided by the use of ballast which is an inconvenience. In flight, the snow is blown off of the surface of the ship, and the only detrimental effect encountered is impaired visibility. It is anticipated, with recent improvements in mechanical handling of airships on the ground, that the ill effects of snow on the ground will be largely eliminated. Chart 11 shows the distribution of days per year with snow cover on the ground. It will be noted a marked decrease in the number of days per year with snow occurs southward and southwesterly from Philadelphia. More desirable conditions are apparent at Richmond.

Rain.—Rain has somewhat the same influence on the operation of an airship as snow. Considerable weight may be added to the craft when moored to a mast, or weight may be added in flight by a heavy shower. Impaired visibility, of course, accompanies rainfall. Chart 14 shows the number of days per year with rainfall and on this chart the entire middle Atlantic seaboard may be considered satisfactory.

For maximum rainfall in any 24-hour period, Chart 16 has been constructed. Here it is obvious that the most desirable location should be an appreciable distance from the seaboard, preferably 50 to 100 miles.

Fog.—In the study of fog, Chart 13 represents the average number of days per year with dense fog. On the chart, the optimum area is inclosed, showing Richmond, Washington, and Philadelphia to be satisfactory. Baltimore is a trifle high, but not seriously so. As is to be expected, the coastal stations of New York, Atlantic City, and Cape Henry are poor.

Docking.—The docking of an airship consists of transferring the ship from its location on the field into the hangar or dock. This operation is usually carried out in favorable wind conditions. It is apparent that a strong cross-hangar wind is productive of severe strains on the airship and some hazard of damage is present. Therefore, favorable wind conditions for docking can be judged by the occurrence of the lower wind speeds.

When the wind velocities are 5 miles per hour or under for one hour or more in 24, this condition is tabulated as a docking day. The average docking days per year are plotted on Chart 18 and the desirable area is inclosed. In the chart some consideration should be given to interpreting the values for Philadelphia and Trenton which were derived from the anemometer exposures of 190 and 180 feet, respectively. These high exposures are productive of higher wind velocity records than are representative for these locations. The optimum area includes Baltimore and Washington, and is very close to Richmond.

"No ground handling."—At higher wind velocities the handling of an airship in close proximity to the ground is somewhat difficult. This may be due to fluctuations in wind speed or turbulence produced by the air flow. The combination of wind fluctuations and the higher force of the strong wind itself can make the handling of an airship on the ground impractical. Such conditions are here described as "No ground handling" conditions. Chart 28 shows as "no ground handling" days, the times per year when winds of 13 miles per hour or over are encountered for the entire 24 hours. The optimum area in this case includes the Baltimore and Washington section.

Mooring delays.—Mooring of an airship consists of anchoring the ship to a high or stub mast by means of cables. This operation is possible in winds of higher velocities, but delay may be encountered when wind velocities of 30 miles or more are encountered.

Mooring delays per year are shown on Chart 34. When winds of 30 miles per hour or more are encountered for a period of 6 to 11 hours, that period is tabulated as a mooring delay. Attention is invited to the shape of the inclosed desirable area which closely approximates the shape of the inclosures of many of the wind charts exhibited in Appendix A. The desirable area includes Philadelphia, Baltimore, Washington, Richmond, and extends on southwesterly. Poor conditions are exhibited at coastal locations.

Distribution of wind velocities.—For another method of studying wind velocities, we have divided the velocities into the following limits: 0 to 5, 6 to 12, 13 to 20, and 21 or more miles per hour. The total number of hours which the wind blew within these velocity limits was used as a basis of this study. For the most desirable conditions we should look for a maximum number of hours for which the wind blew within velocity limits of 0 to 5 miles per hour, and conversely, a minimum number of hours for velocities of 6 or more miles per hour.

Chart 43 shows the total number of hours per year, averaged from 5-year data, that the wind blew within velocity limits of 0 to 5 miles per hour. The inclosed optimum area extends northward nearly to Philadelphia. There may be some question as to Hadley Field being included in the desirable area due to the break in conditions exhibited in the vicinity of Philadelphia. No accurate method was available to justify the exclusion of this station, and it was therefore included.

For velocity limits of 6 to 12 miles per hour, wind conditions are shown on Chart 44 giving total hours per year for this velocity limit. The inclosed optimum area has the usual characteristic shape with the exception that it includes Mitchell and Hadley Fields usually excluded on other charts.

Velocity limits of 13 to 20 miles per hour are shown on Chart 45. The shape of the optimum area is of the usual type with the exception that it includes Hadley Field in the area.

For velocity limits of 21 or more miles per hour, the hours per year are shown on Chart 46, showing the characteristic shape of the desirable area which includes Philadelphia, Baltimore, Washington, and Richmond.

Hangar orientation.—For study of wind direction applicable to hangar orientation the polar coordinate charts, Nos. 64 and 65, are incorporated as representing typical direction studies. It will be noticed on Chart 64, the days and nights with low winds of 0 to 5 miles per hour were excluded and the chart covered only those periods in which winds of 6 to 12 miles per hour were encountered for one or more hours. Some question may be raised as to the desirability of excluding those periods in which docking conditions of 0 to 5 miles per hour exist, but it was felt that the inclusion of those periods would merely mean the addition of a constant value to the radii of Chart 64. The prevailing wind direction is shown as a maximum westerly direction on this chart.

On Chart 65 the distribution of wind directions and velocities is shown by various limits of 6 to 12, 13 to 20, and 21 or more miles per hour. The wind direction on the chart is somewhat variable, but quite desirable from

a velocity viewpoint, showing predominance of winds of low velocities and low frequency of winds of a higher velocity.

SUMMARY

For a summation of the precipitation, fog, thunderstorm, and temperature conditions Chart 1 was devised. This chart represents a composite of *all* conditions other than wind, taken from Appendix A and superimposed upon each other to obtain the most desirable or optimum area. The shaded area in the chart represents the optimum area and includes Philadelphia and Washington. The isogram to the west of Washington is a temperature line, and therefore may be considered somewhat flexible, sufficiently so to justify the inclusion of Washington and perhaps Richmond in this area. Baltimore is slightly below normal on fog conditions. Richmond has slightly more thunderstorms and slightly higher summer temperatures but should be included in the desirable area.

Chart 2 represents a composite summary of all wind conditions described in Appendix A. The optimum area is shaded in this chart and lies slightly to the westward of Philadelphia and to the north of Richmond. Only one or two lines exclude Richmond and Washington from the optimum area, and therefore they should be included in that area. There is an apparent transition in the weather conditions in the vicinity of Philadelphia, becoming increasingly poor to the northeast. Therefore, as a northern limit to the desirable area, Philadelphia is included. Comparatively few lines exclude Richmond, which is likewise recommended for the desirable area.

Anticipating the development of mechanical handling of airships in higher wind velocities than has been common in the past, we have provided in Chart 3 a summary of all wind conditions and velocities of 21 miles per hour or more. This composite chart was likewise obtained from superimposing all wind charts above 21 miles per hour shown in Appendix A of this study and the optimum area is shown in the shaded portions. Philadelphia represents the northeastern limit of this area which also includes Baltimore. Richmond is excluded by a single line and Washington is in close proximity to the desirable area and these cities are, therefore, recommended to be included in the optimum area.

COMPARISON OF STUDY AND INDEPENDENT STUDIES

In order to align this study with similar efforts we have provided Chart 4, comparing the centers of the desirable areas with the average wind velocities. The lines for average wind velocities are taken directly from the Atlas of American Agriculture, Part 2, Section B, by J. B. Kincer. This phase of the chart was based on anemometer records of the 20-year period from 1891 to 1910, inclusive, taken at 175 Weather Bureau stations scattered throughout the United States. Corrections were applied for the heights of the anemometers to estimate the wind that would have occurred at the uniform elevation of 100 feet above the ground. It will be noted that a marked increase in velocity occurs from the Atlantic seaboard to the west and that the desirable area based on average wind velocity conditions alone would include Washington, Philadelphia, Baltimore, and Richmond. Low temperatures and snow would limit the northern extent of the area to Philadelphia, while the southern cut-off would occur south of Richmond due to high temperatures and thunderstorms.

To compare the average velocity features of Chart 4 with our study, a line in the center of the optimum area of each chart was drawn to represent the locus of maximum desirability. All charts in Appendix A, including the climatological and wind charts, were thus treated and superimposed on the average wind velocities of Chart 4. Obviously the location where the lines are the densest may be considered the optimum area. It is a striking feature of this comparison that the loci of the optimum points coincide with the desirable area as indicated by the average wind velocities. It is certainly to be expected that the various methods should be in reasonable agreement but in this case the conclusions are identical.

CONCLUSIONS

In Appendix A the statement is made that an examination of the study will show the desirability of keeping at least 30 miles back from the shore line of the Atlantic seaboard. This statement was based largely on summaries shown on Charts 2 and 3 showing the eastern edge of the optimum area to have a very definite relation to the Atlantic coast. However, if we wish to secure the most perfect conditions possible near the eastern seaboard, it would appear that, based on the evidence on Chart 4, the airship base should be about 100 miles from the Atlantic coast. This statement is in agreement with our present conception of the influence of large bodies of water. We know definitely from temperature studies, free balloon flights, and similar phenomena that the direct influence of the sea breezes extends at least 30 miles inland. Further, it is also reasonable, as indicated by this study, that the complete dampening influence of the surface friction of the land area is not fully effective until a distance of about 100 miles from the Atlantic seaboard has been reached.

It should not be inferred that ideal conditions will be encountered 100 per cent of the time in any section of the middle Atlantic seaboard. However, from the data herein presented, it will be seen that in the desirable areas outlined in this study, the best attainable conditions will be encountered. By using the weather conditions encountered at the Naval Air Station at Lakehurst, N. J., as a standard of comparison, it is apparent that the operating conditions to be encountered at the proposed locations of Richmond, Washington, Baltimore, and Philadelphia will be very much better than those of Lakehurst.

In conformity with the conclusions of this study and Appendix A, we recommend that the locations of Richmond, Washington, and Baltimore be considered for a trans-Atlantic airship base, and also that Philadelphia be included as representing the most northerly point that we can conscientiously recommend for consideration. On these four locations anemometers have been erected and continuous records are being taken of wind velocity and direction characteristics, and the final selection of an airship base will be made largely from records thus obtained. Such records are necessarily affected largely by local topography which influence may modify the general views developed from the preliminary and general survey made in this report. It is only to be expected that in the large area here found to be generally favorable there may be locations that are more favored by nature than others.

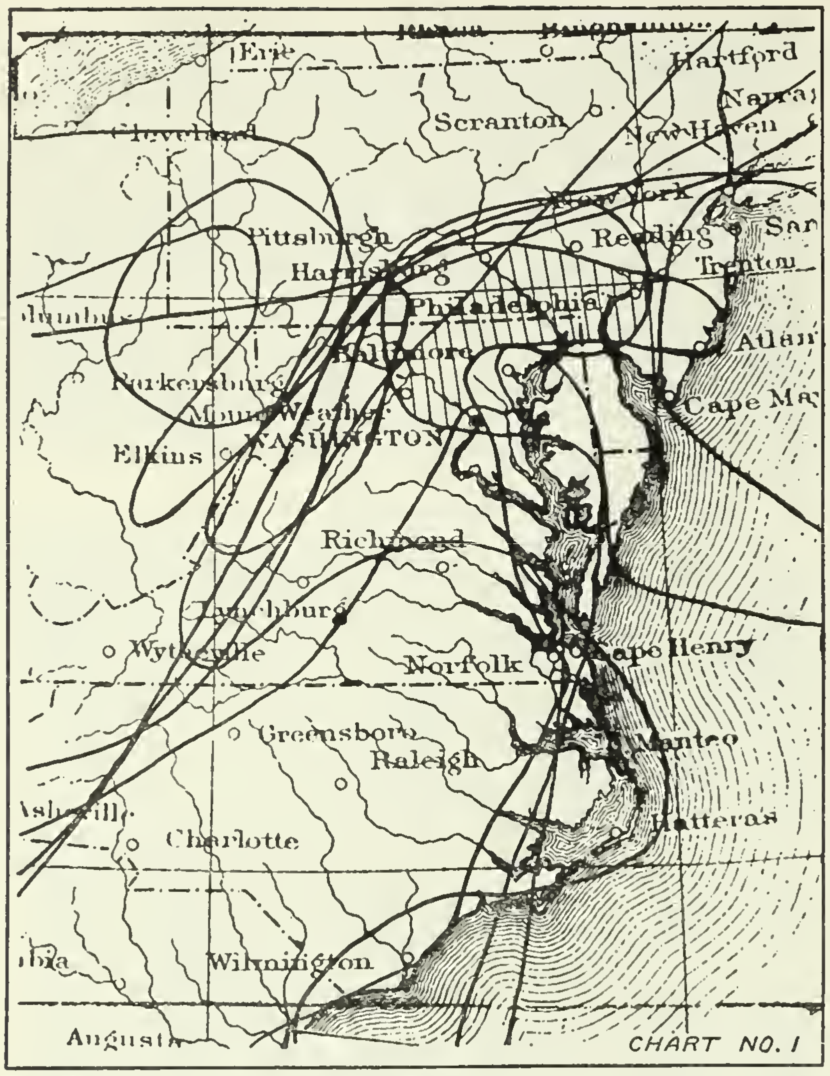

FIGURE 1 (CHART 1).—Summary of precipitation, fog, clouds, thunderstorms, and temperatures

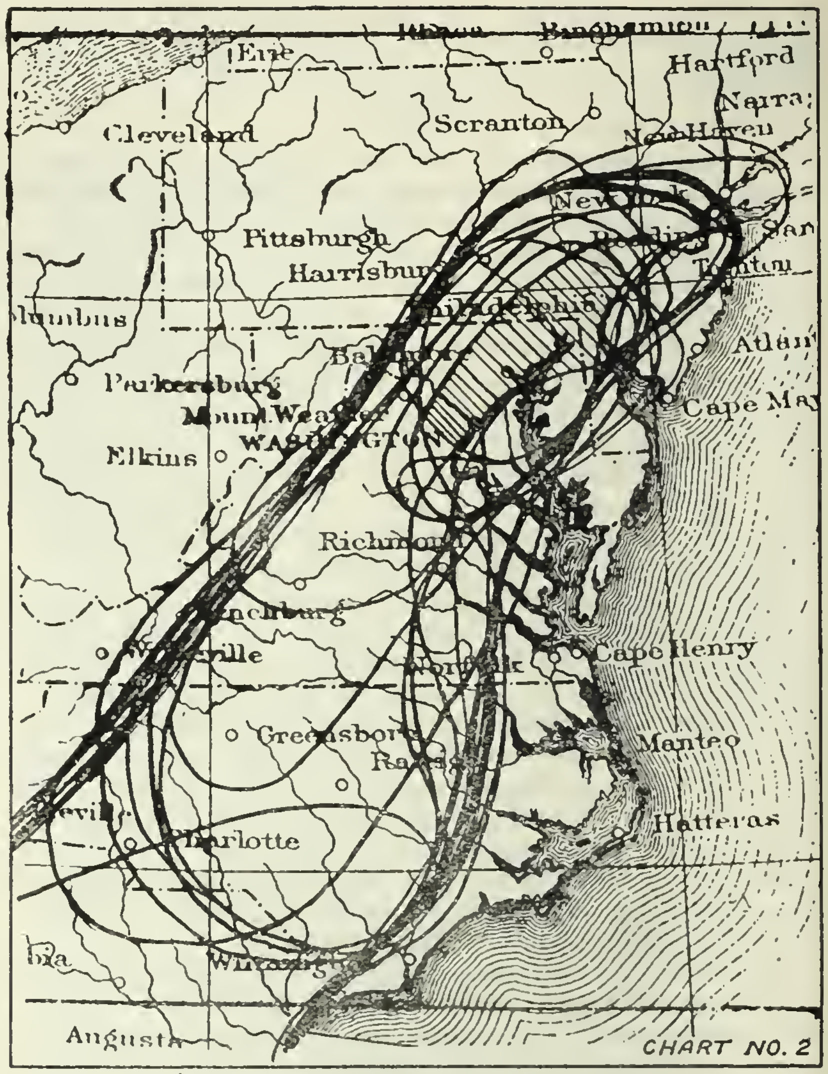

FIGURE 2 (CHART 2).—Summary of all wind conditions, shaded area most desirable

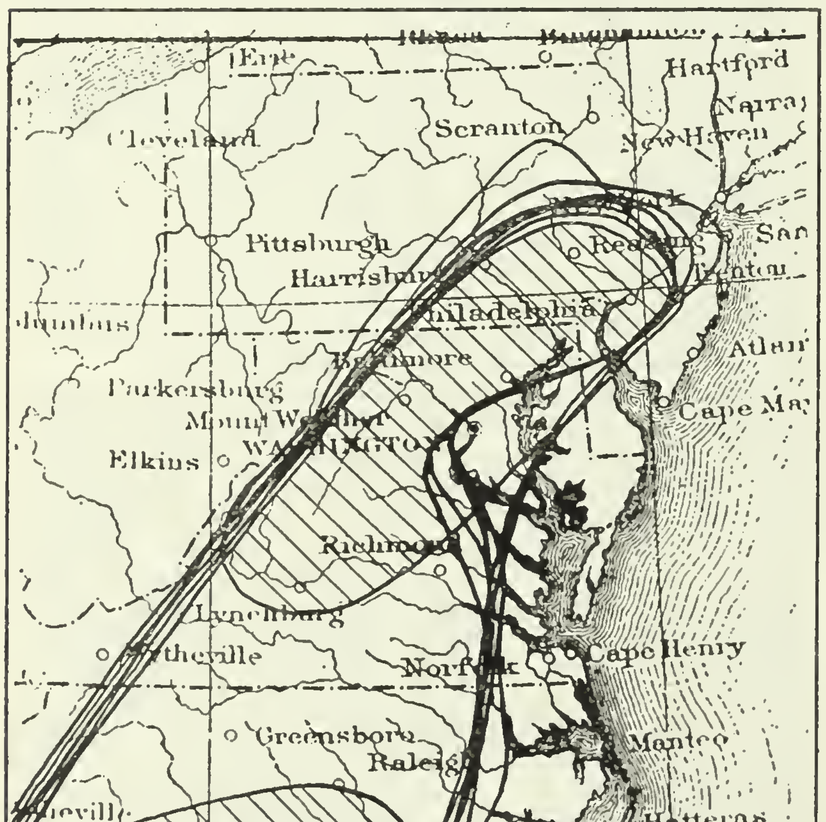

FIGURE 3 (CHART 3).—Summary of winds of 21 or more miles per hour

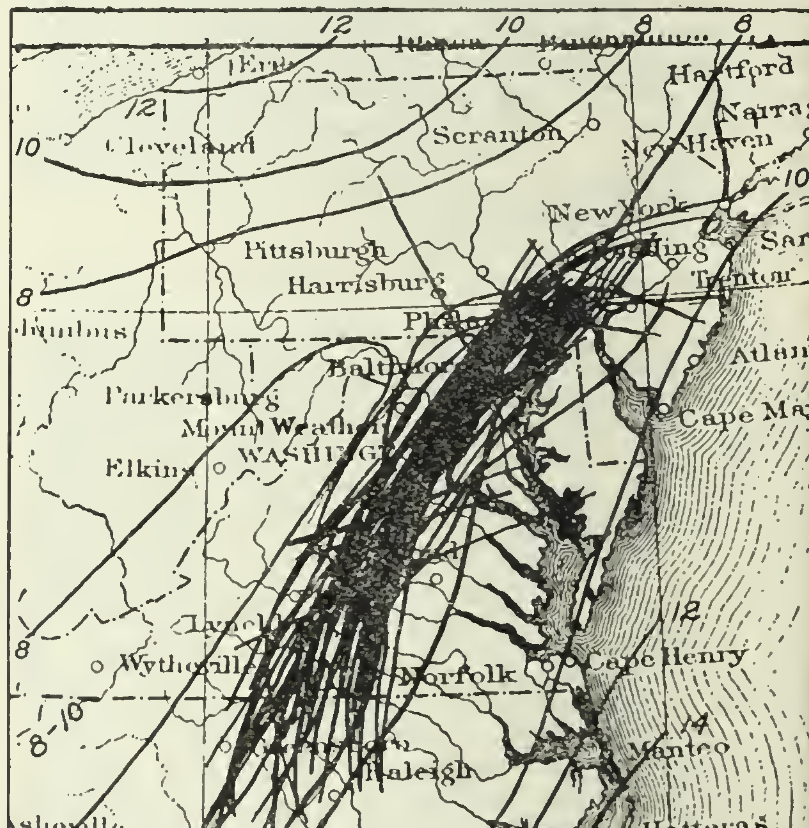

FIGURE 4 (CHART 4).—Centers of optimum areas compared to average wind velocities in miles per hour

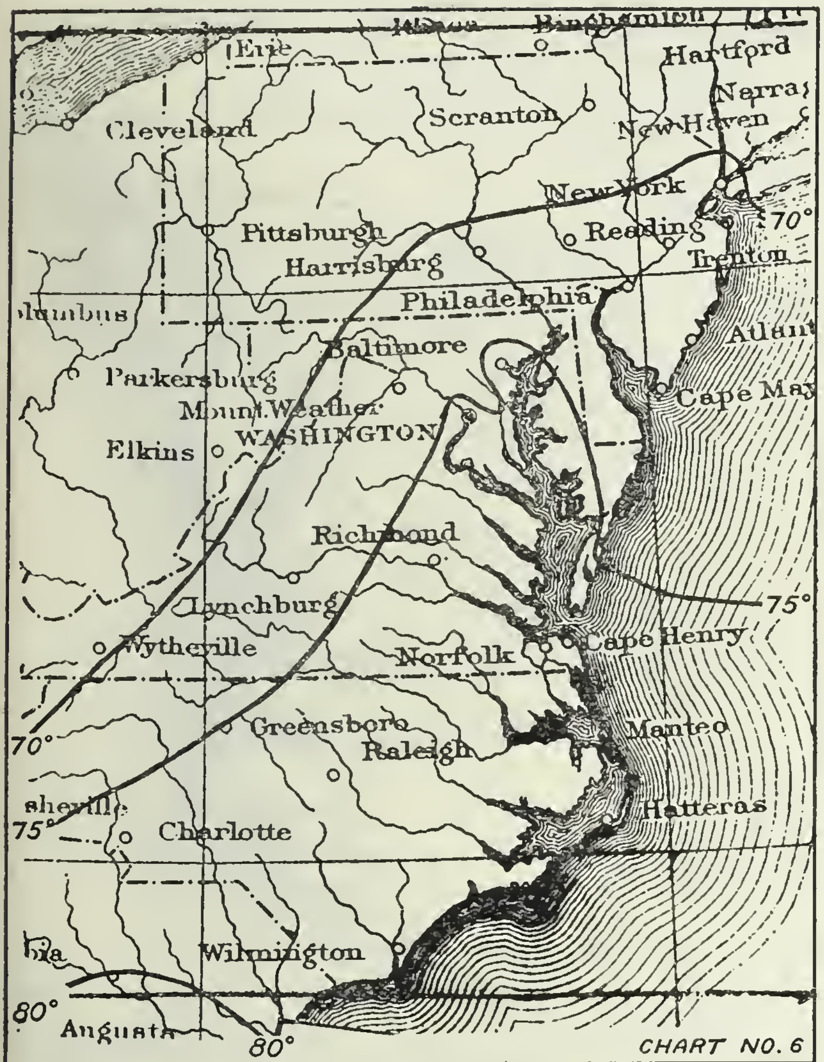

FIGURE 5 (CHART 6).—Average summer temperature, June, July, and August, 1895-1914

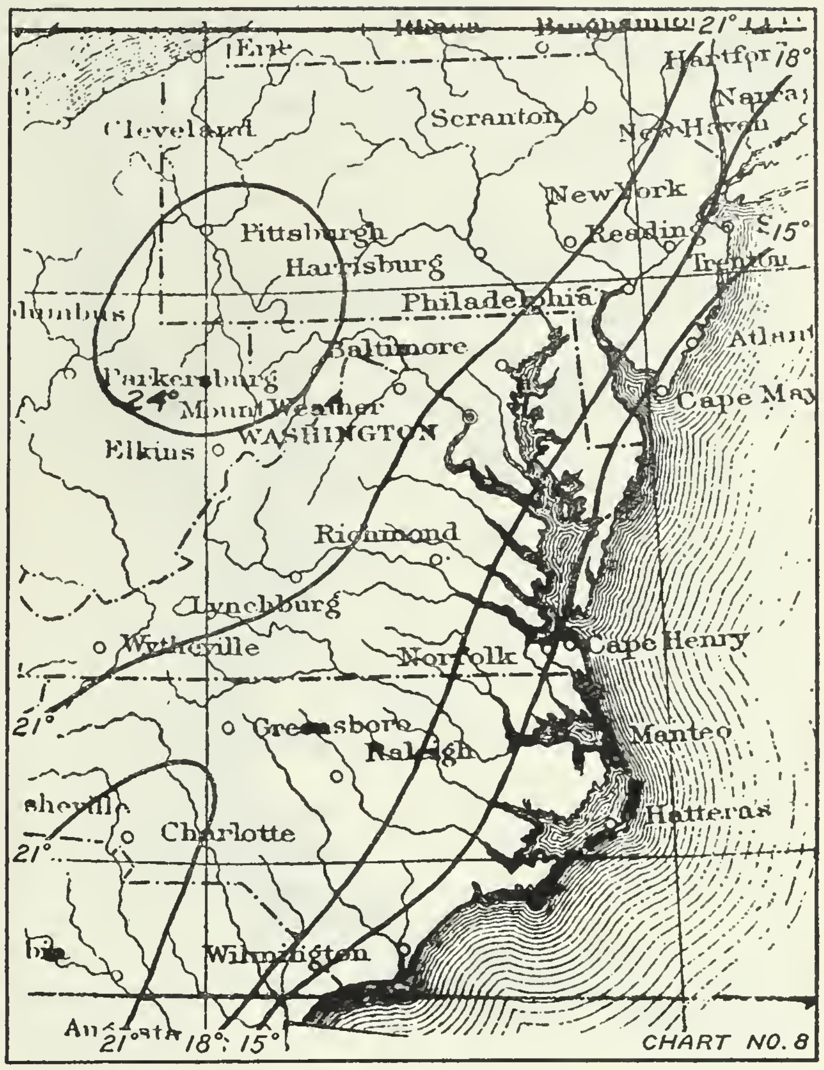

FIGURE 6 (CHART 8).—Average daily temperature range, July, 1895-1914

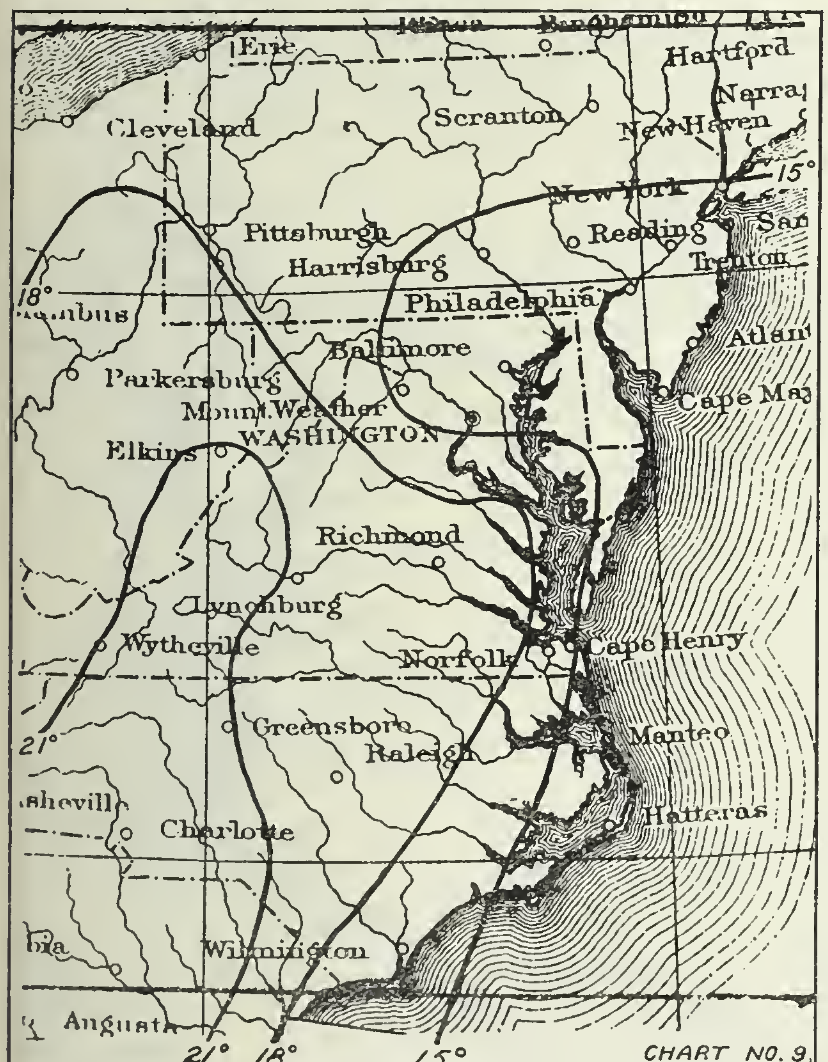

FIGURE 7 (CHART 9).—Average daily temperature range, January, 1895-1914

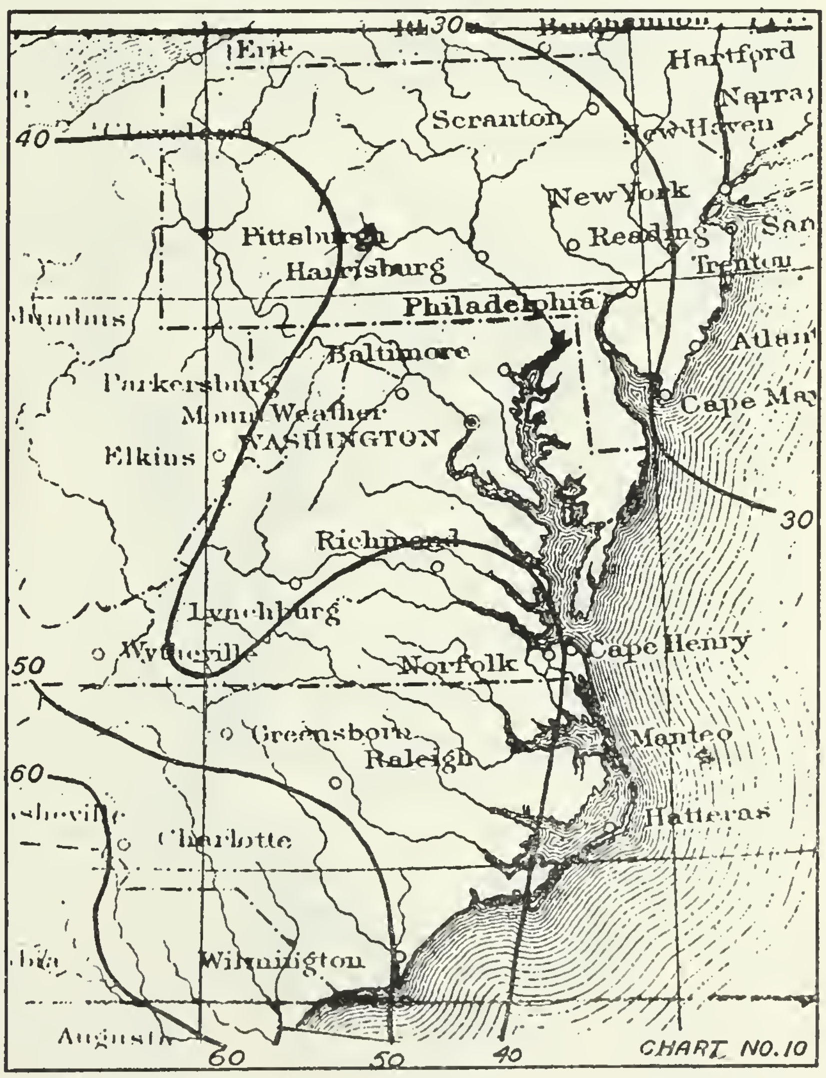

FIGURE 8 (CHART 10).—Average number of days with thunderstorms per year, 1904-1913

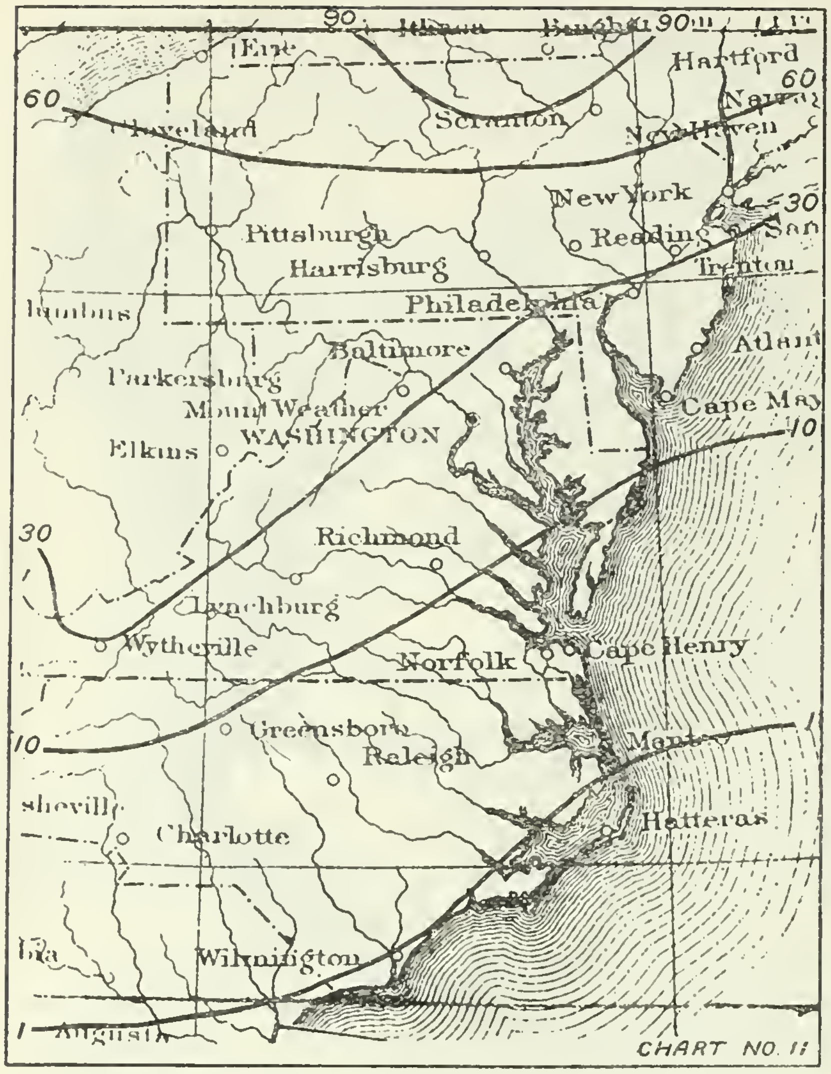

FIGURE 9 (CHART 11).—Average number of days with snow cover per year, 1895–1914

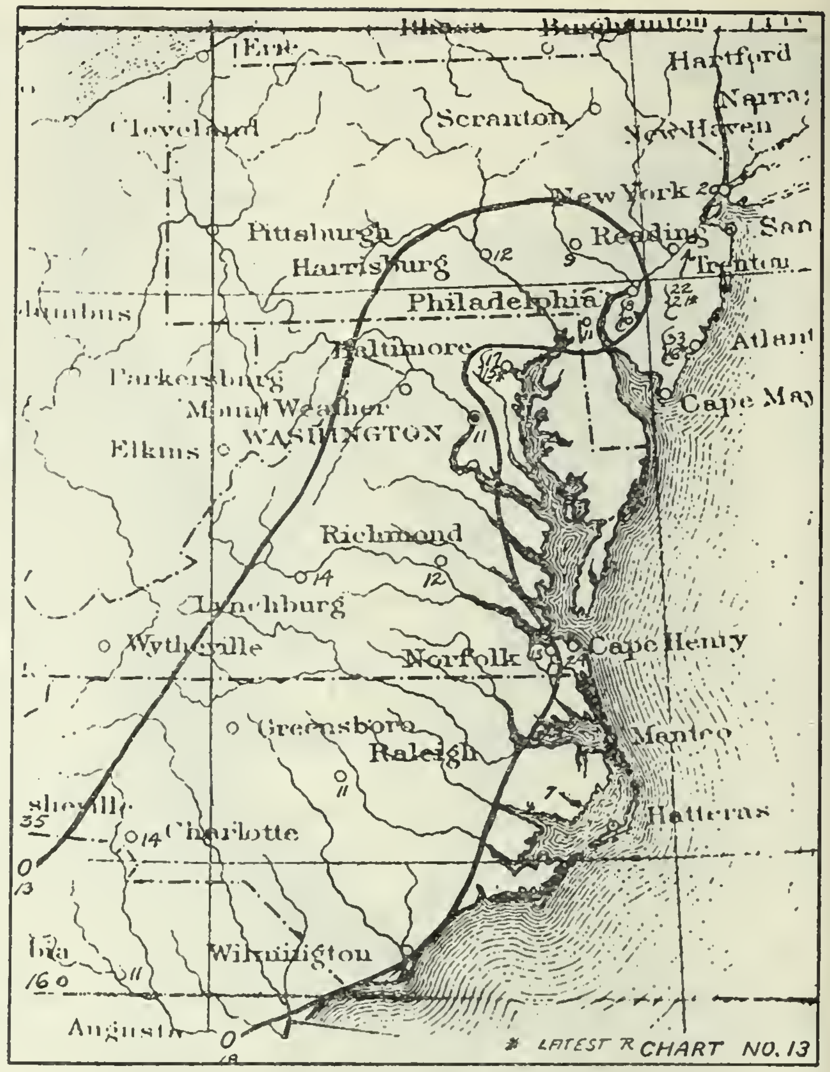

FIGURE 10 (CHART 13).—Average number of days with dense fog

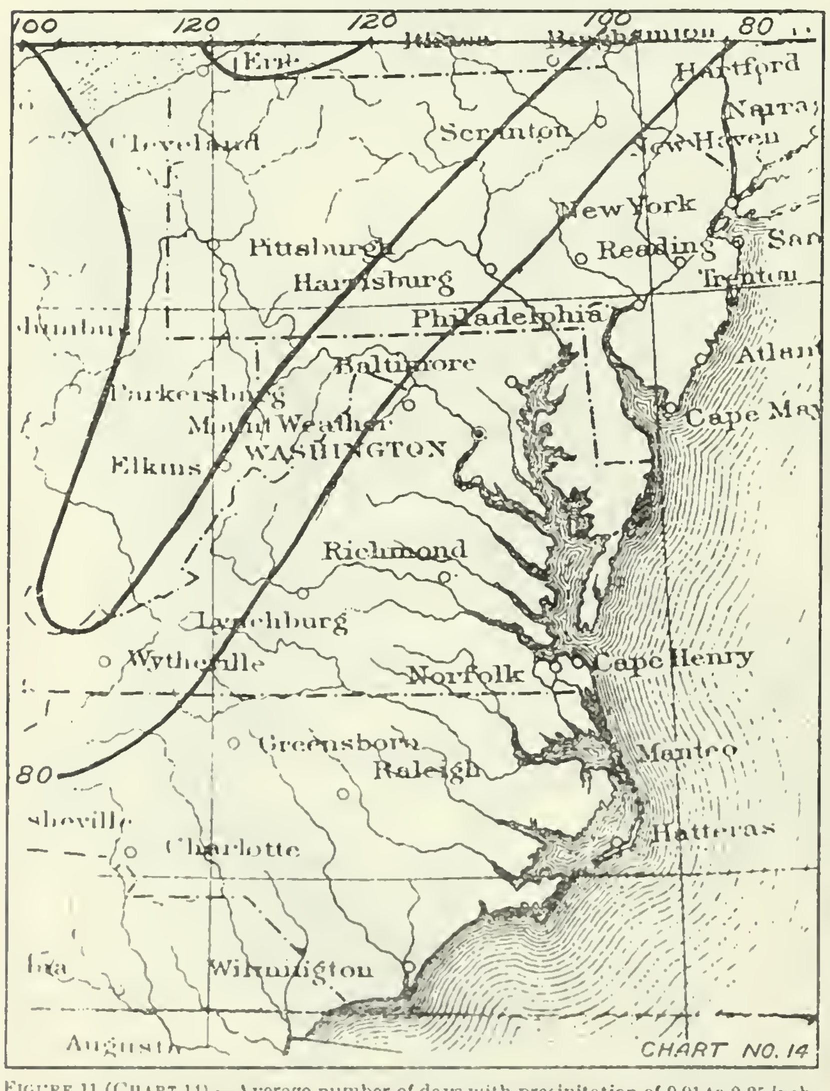

FIGURE 11 (CHART 14).—Average number of days with precipitation of 0.01 to 0.25 inch, 1895–1914

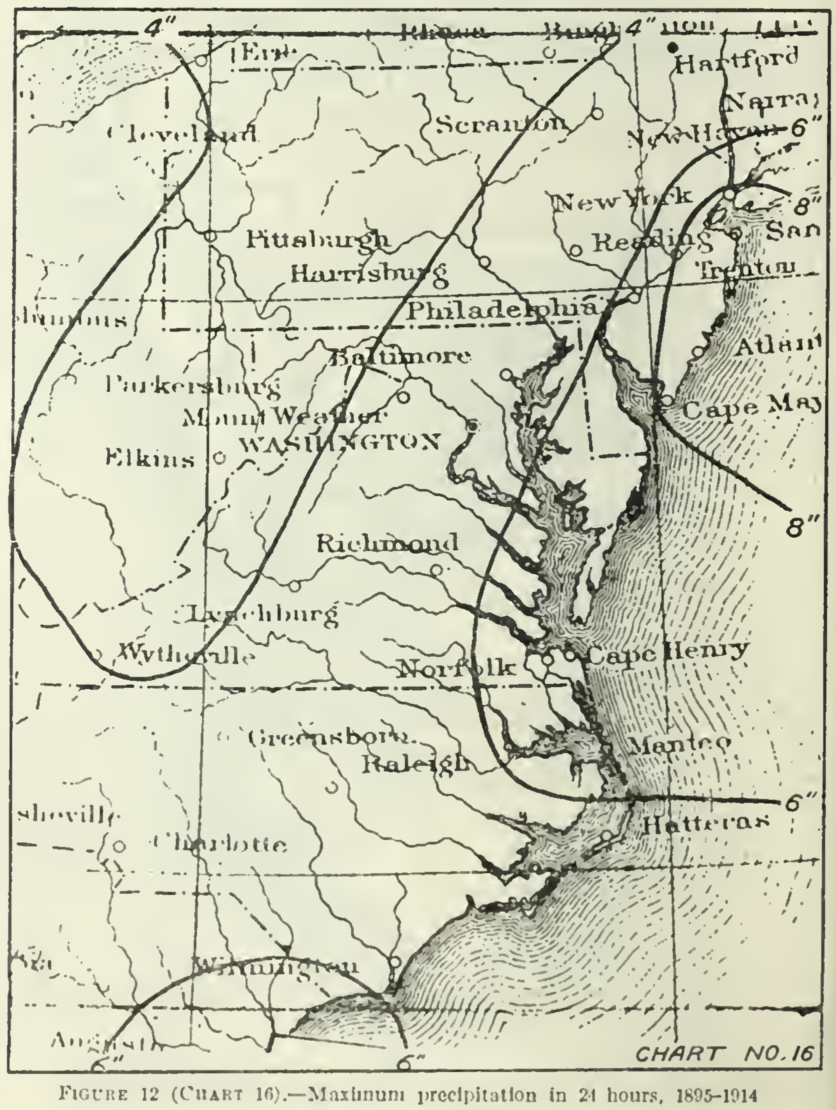

FIGURE 12 (CHART 16).—Maximum precipitation in 24 hours, 1895–1914

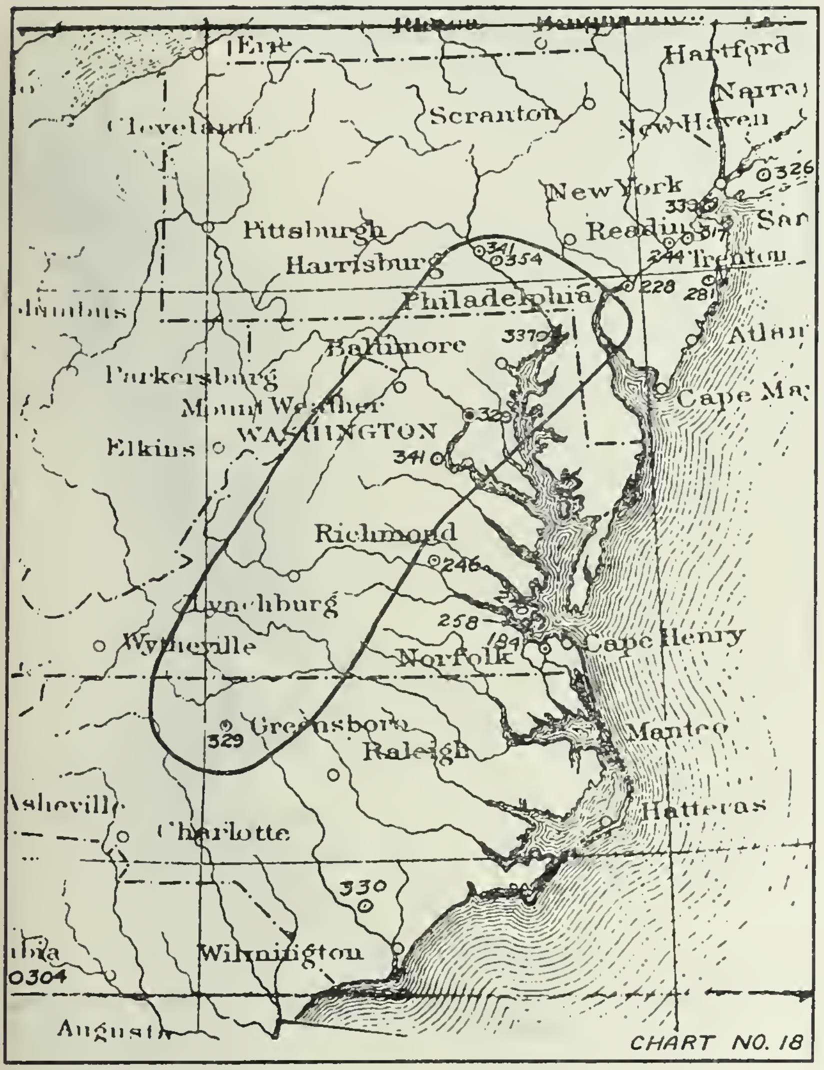

FIGURE 13 (CHART 18).—Docking days, 24 hours, winds of 5 miles per hour or under, for 1 hour or more

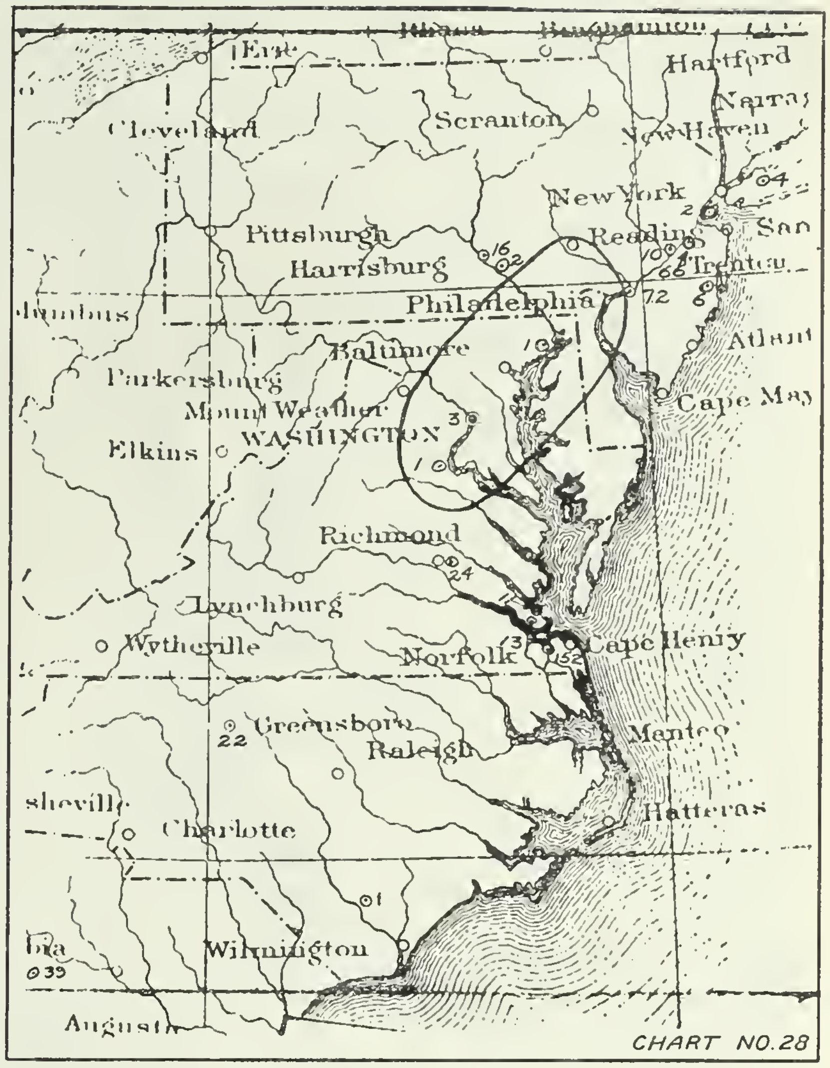

FIGURE 14 (CHART 28).—"No ground handling" days, winds of 13 miles per hour or over for entire 24 hours

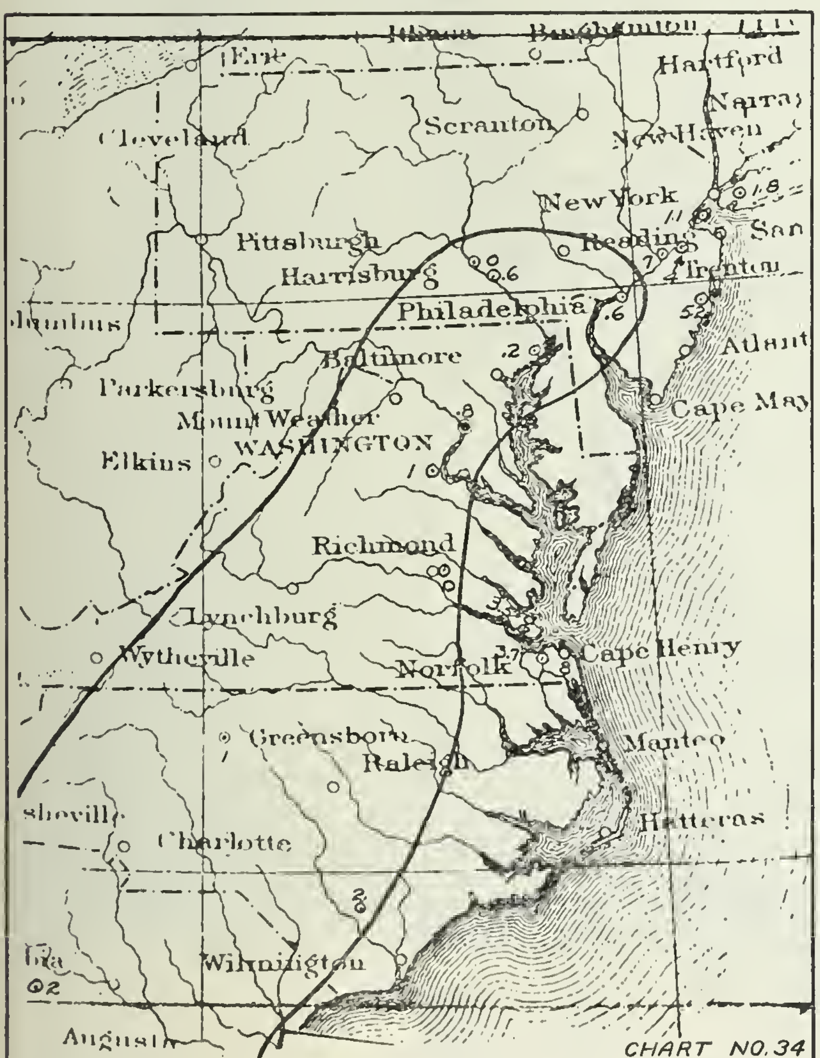

FIGURE 15 (CHART 34).—Mooring delays, winds of 30 miles per hour or more, periods of 6–11 hours

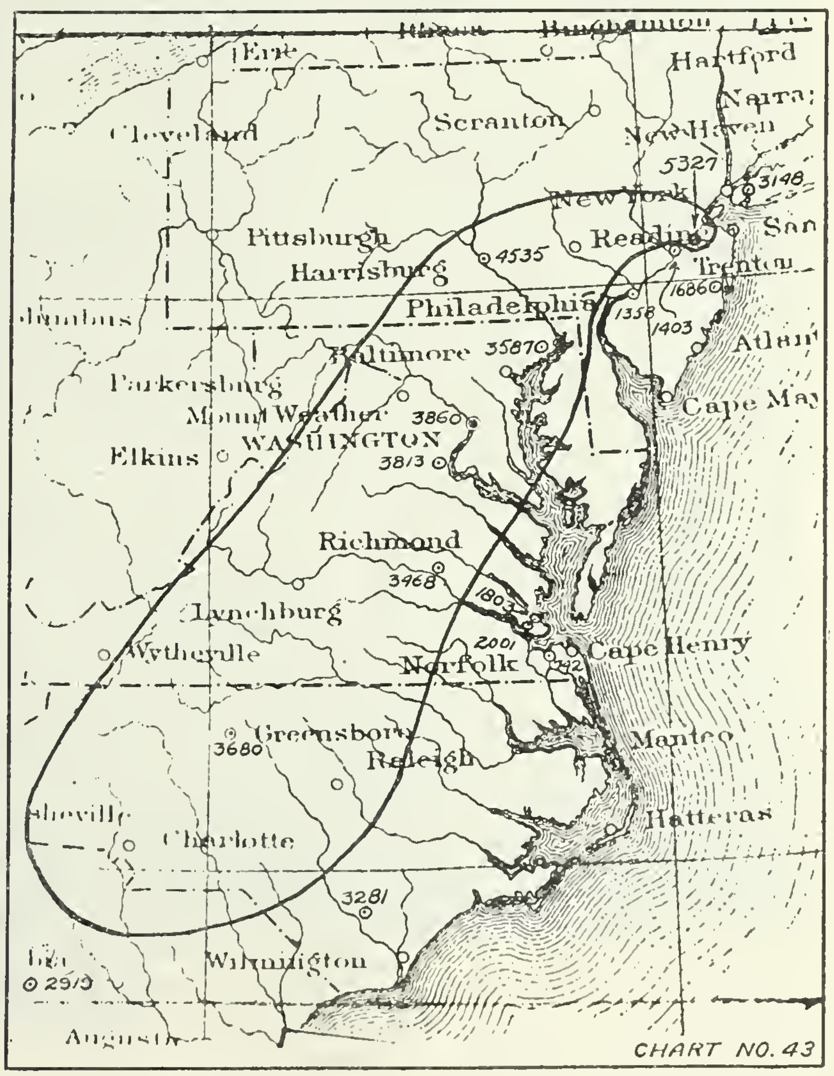

FIGURE 16 (CHART 43).—Hours per year, winds of 0–5 miles per hour

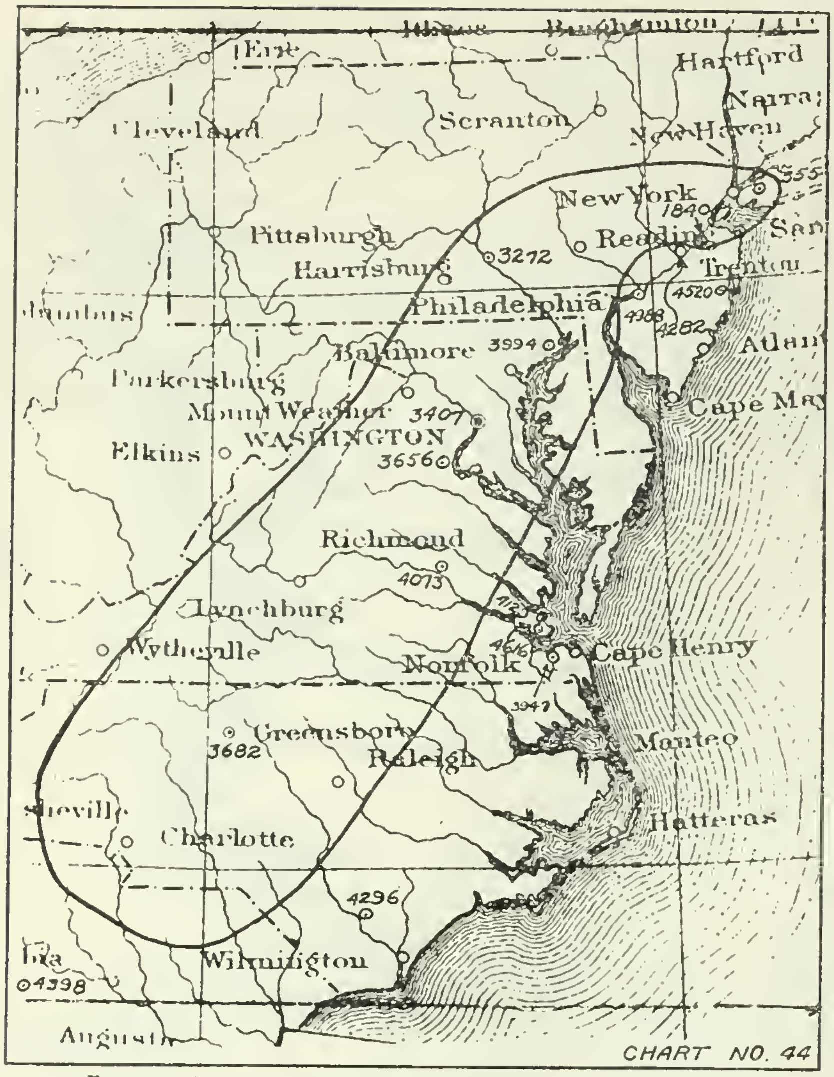

FIGURE 17 (CHART 44).—Hours per year, winds of 6-12 miles per hour

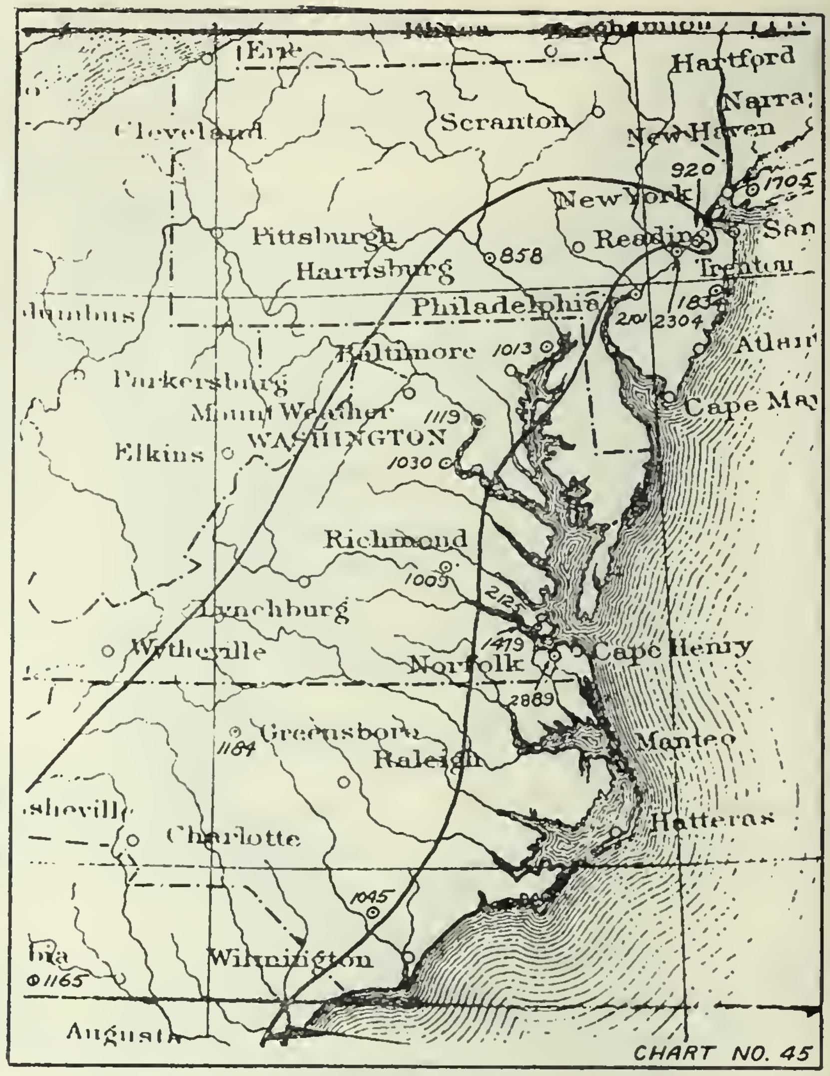

FIGURE 18 (CHART 45).—Hours per year, winds of 13-20 miles per hour

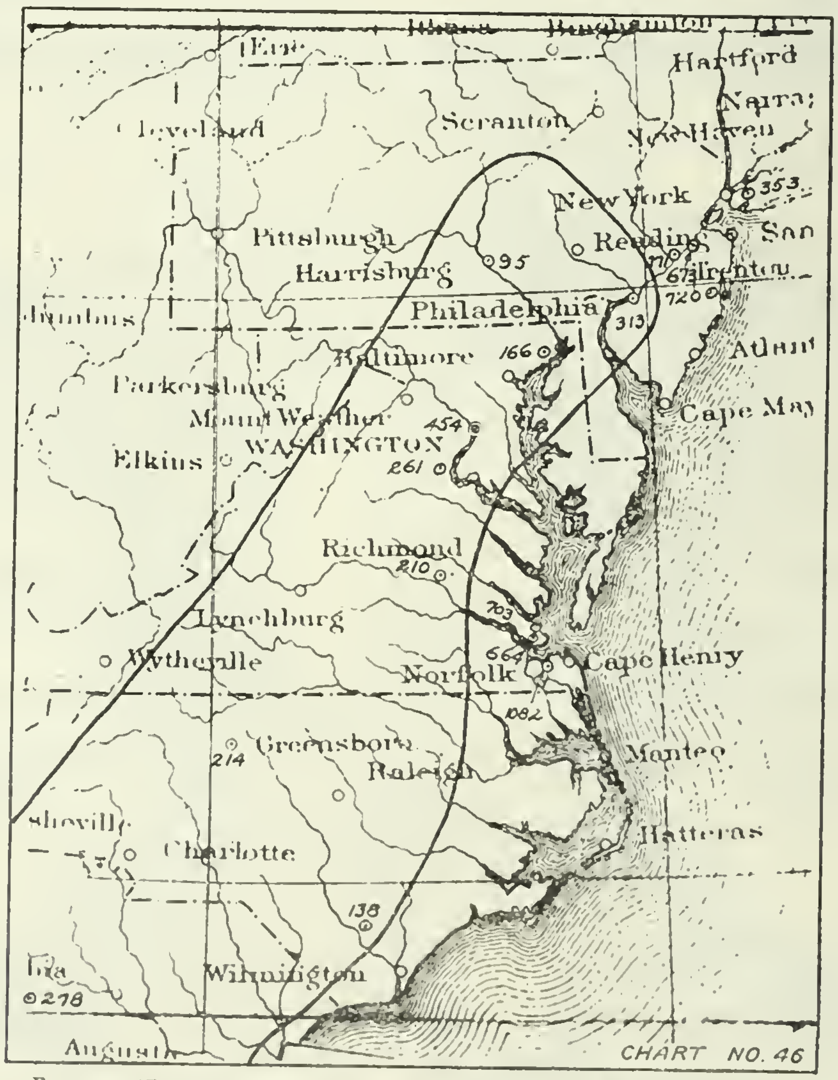

FIGURE 19 (CHART 46).—Hours per year, with winds of 21 miles per hour or more

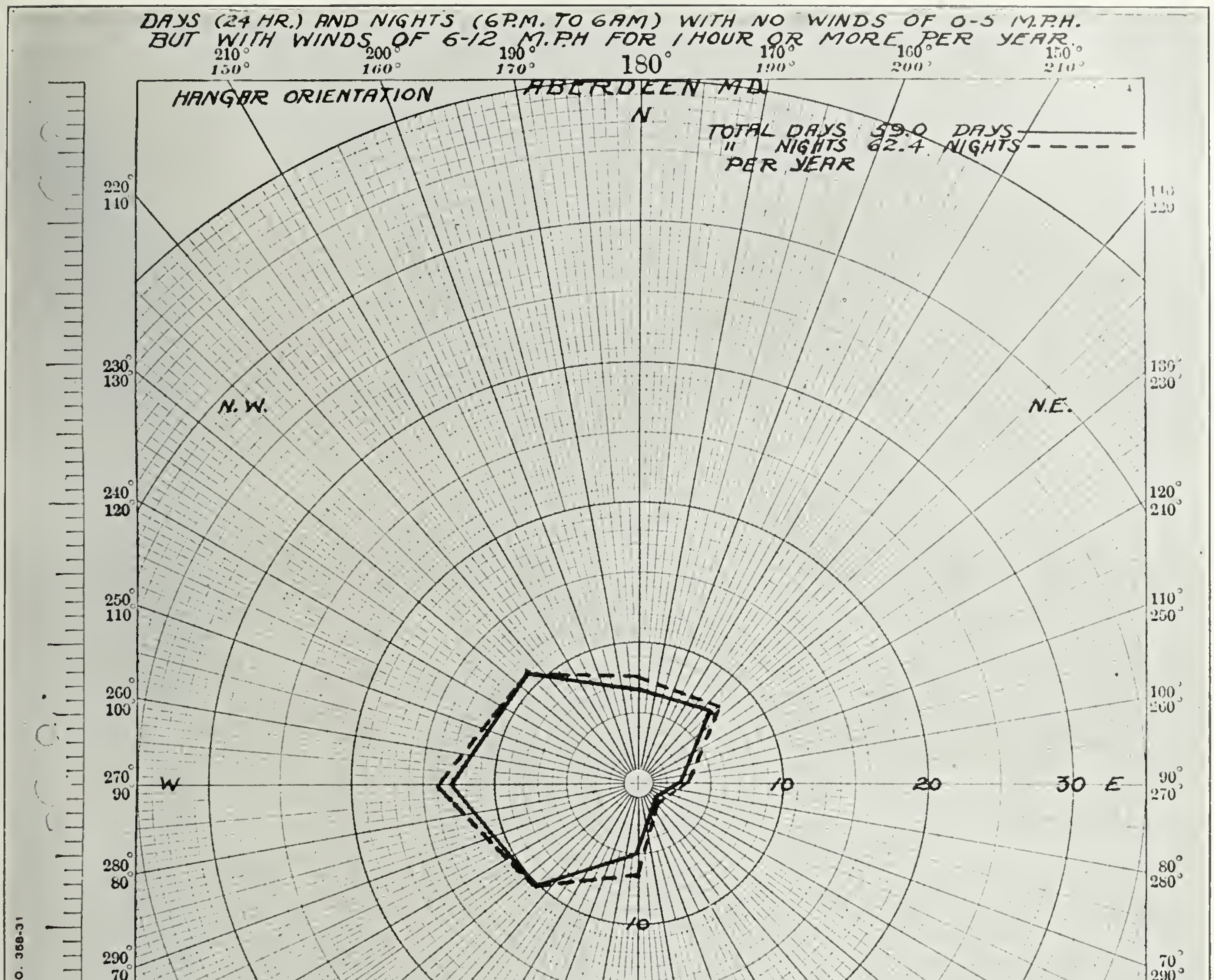
DAYS (24 HR.) AND NIGHTS (6P.M. TO 6AM) WITH NO WINDS OF 0-5 M.P.H. BUT WITH WINDS OF 6-12 M.PH FOR 1 HOUR OR MORE PER YEAR.
HANGAR ORIENTATION
ABERDEEN MD.
TOTAL DAYS 59.0 DAYS
" NIGHTS 62.4 NIGHTS
PER YEAR
N
N.W.
N.E.
W
E
S.W.
S.E.
S
10
20
30
40
CHART NO. 64
KEUFFEL & ESSER CO. N. Y. NO. 358-31
Polar Co-ordinate

FIGURE 20

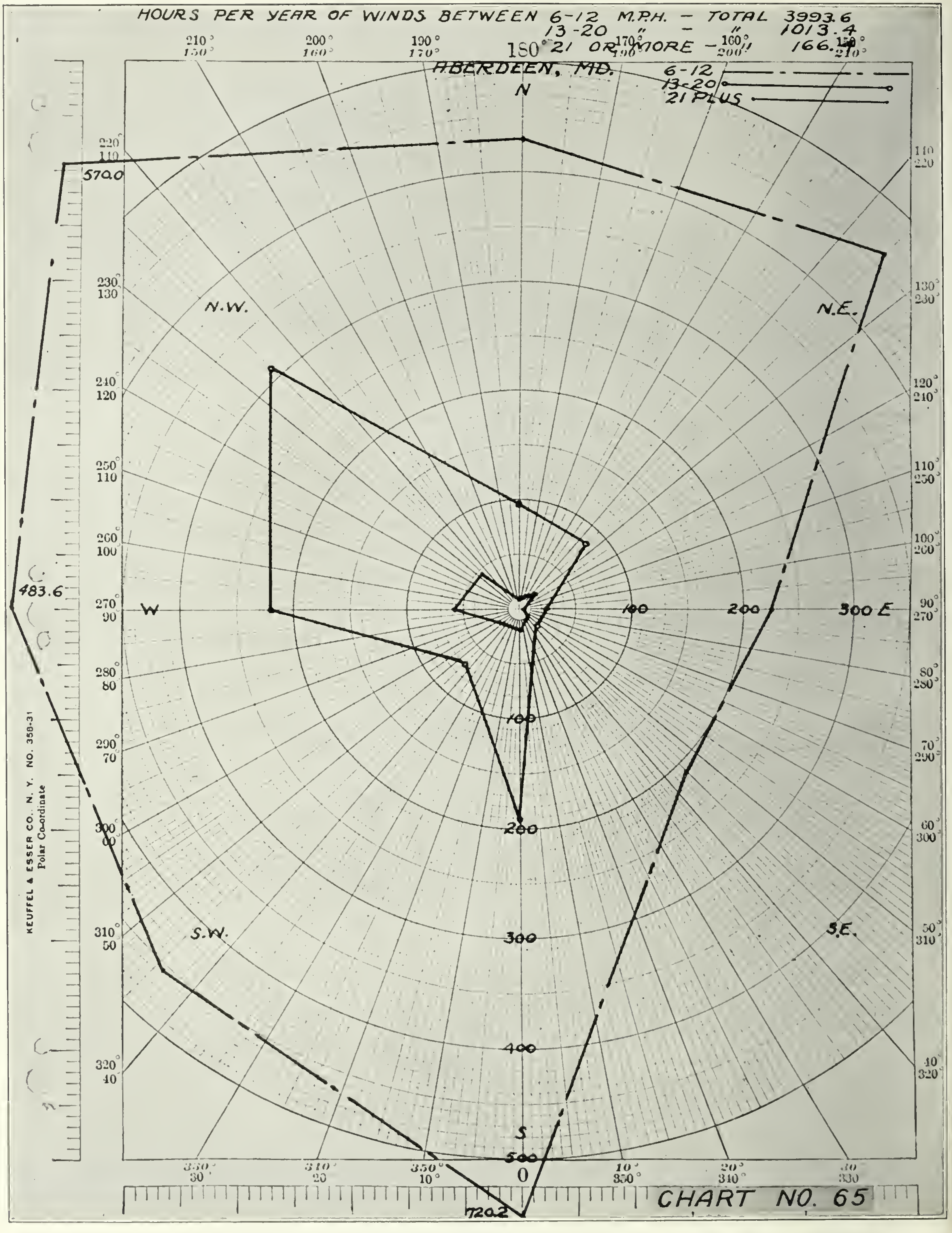
HOURS PER YEAR OF WINDS BETWEEN 6-12 M.P.H. — TOTAL 3993.6
13-20 " — " 1013.4
21 OR MORE — " 166.
ABERDEEN, MD.
6-12
13-20
21 PLUS
N
N.W.
N.E.
W
300 E
S.W.
S.E.
S
570.0
483.6
720.2
100
200
300
400
500
KEUFFEL & ESSER CO. N. Y. NO. 358-31
Polar Co-ordinate
CHART NO. 65

FIGURE 21

NEW LIGHT ON THE BEGINNINGS OF THE WEATHER BUREAU FROM THE PAPERS OF INCREASE A. LAPHAM

By Eric R. Miller

[Weather Bureau, Madison, Wis.]

The papers of Increase A. Lapham, given to the Wisconsin Historical Society by his daughter, contain a great deal of important material for the history of meteorology. To understand how Lapham occupied an important place in this history it is necessary to briefly sketch his life and work.

Born at Palmyra, N. Y., in 1811, the son of a contractor on the Erie Canal, Lapham spent nearly half his life amidst the digging of canals and the building of locks. The strata exposed in cutting the canals, the minerals, shells, fossils, Indian remains, and the plant and animal life of the wild country became matters of prepossessing interest to him. Pursuit of this interest led him to read every scientific book and journal that he could lay hands on, and to correspond with men of science, seeking light on the problems that confronted him. Benjamin Silliman, founder of the American Journal of Science, took great interest in him, and published his first paper (**1**) written at the age of 16.

Beginning as rodman on the Welland Canal, Lapham entered the profession of civil engineer. On the Miami Canal he became assistant engineer under Byron Kilbourn who remained his lifelong friend. A shift of canal-building activity to the Ohio Valley placed Lapham on the staff of the Ohio State Board of Canal Commissioners, as assistant engineer at Portsmouth, afterwards as secretary with office in the capitol at Columbus where he urged upon the legislature (1835) the importance of a geological survey and was placed by the legislature on its committee and made a preliminary survey of the geological resources of Ohio (**2, 3**).

Political change abolished the canal board in 1836, and caused Lapham to emigrate to Milwaukee where he joined Kilbourn on the Milwaukee and Rock River Canal, and rose through the grades of engineer, chief engineer, to secretary before railway building ended the project in 1845. Surveying, reporting on mines and quarries, publishing maps and guidebooks afforded his livelihood, but he found time to devote to observing, collecting, classifying, and describing. In the 47 years from the publication of his first paper until his death in 1875, Lapham published 44 important papers, mostly in the transactions of learned societies in the Middle West. A survey of the Indian mounds of Wisconsin, financed by the American Antiquarian Society was published by the Smithsonian Institution (**4**).

Generosity in exchanging specimens brought Lapham an ever-widening circle of correspondents. Of names still well known his letter files include Asa Gray, John Torrey, W. S. Sullivant, George Englemann, W. J. and J. D. Hooker, Leo Lesquercux, Louis Agassiz, James Hall, Alexander Winchell, J. D. Dana, H. R. Schoolcraft, Joseph Henry, J. P. Espy, M. F. Maury, Lorin Blodget. Even Brigham Young wrote for seeds of grasses to plant in Utah. He was elected corresponding member of a long list of academies, ranging from the Royal Society of Northern Antiquaries of Copenhagen on the east to the California Academy of Sciences on the west. The honorary degree of LL.D. was bestowed by Amherst College in 1860, and that body of American "immortals" the American Philosophocal Society of Philadelphia elected him to membership in 1874 after he had become chief geologist of Wisconsin.

Civic, educational, and scientific organizations always claimed Lapham's enthusiastic support. He organized a lyceum at Portsmouth, in 1832, was member, curator of collections, and treasurer of the Historical and Philosophical Society of Ohio, and member of the Western Academy of Natural Science at Cincinnati in 1834 and 1835. At Milwaukee he was active in the County Agricultural Society (secretary, 1837), Lyceum (secretary, 1839), Library Association (director, 1847), Young Men's Association, Sons of Temperance. Of State societies he was active member of the Minnesota Historical Society (1851), Historical Society of Wisconsin (corresponding secretary 1851, life membership 1855), Academy of Natural Science of Chicago (chairman of geology, 1857), Iowa Historical Society (1857), Upper Mississippi Valley Historical Society (1863), Wisconsin Academy of Sciences, Arts, and Letters (one of the five founders, and first secretary, 1870). In 1847 the Milwaukee city council appointed Lapham to negotiate a loan for building schoolhouses, and he donated 13 acres for the high-school site. He was one of the founders of the Milwaukee Female Seminary (Milwaukee-Downer College) and in 1850 as president of the governing board presented diplomas to the first graduating class.

Meteorology seems to have first come to his attention in a letter from his brother Darius, in 1840, outlining Espy's theory of storms. This he gave to the Milwaukee Advertiser for publication, and brought the subject up for debate in the lyceum, with the result that he and Carl J. Lynde were deputed to make weather observations, a duty that they performed from December, 1840, to March, 1842. Espy himself sent Lapham blank forms and requested his cooperation in July, 1842, but Dr. E. S. Marsh was prevailed upon to undertake this work until he joined the rush to California in January, 1849. Lapham then acted as interim observer until 1853, when news arrived of the death of Marsh in the explosion of the boiler of the steamer *Louisiana* on which he was returning. Carl Winckler, a druggist then observed from 1853 to 1858. At the end of 1858, Captain Meade (afterward generalissimo at Gettysburg) was organizing a net of meteorological and hydrographic observers for the Lake Survey, and asked Lapham to undertake the work at Milwaukee. In performing this duty, from 1859 to 1872, Lapham prepared elaborate summaries of his own and his predecessors observations, working out hourly mean pressures and temperatures, 20-year daily means, etc. At the same time he cooperated with the local press, and with the State agricultural and horticultural societies, preparing climatological tables for all places in that State at which observations had been made. He had written articles on Wisconsin climate for periodicals like the Northwestern Journal of Education (pp. 117–120, 1850), the American Almanac (1852, pp. 102), Chicago Academy of Sciences (vol. 1, pt. 1, pp. 58–60).

Shipwrecks on the Great Lakes were a matter of grave concern to Lapham, hence when the reports of Espy, formulating the laws of storms were published, Lapham began agitating for their practical application. In January, 1850, his propaganda, supported by memorials from

the Milwaukee Board of Trade and the Wisconsin Agricultural Society, and a list that he prepared of the disasters on the Lakes in 1848 and 1849, induced the Wisconsin Legislature to consider a bill establishing a State weather service, with 29 stations, 1 in each county, after the Pennsylvania pattern, but with telegraphic reports to Milwaukee. After apparently favorable progress the bill failed to pass. In the hope of convincing doubting legislators Lapham, with the cooperation of Asa Horr, at Dubuque, timed the passage of barometric troughs across Wisconsin, and found that six to eight hours elapsed. These tests were made in 1853, and again in 1860–61. Starting of car-ferry service between Grand Haven and Milwaukee by the Detroit & Milwaukee Railway, in 1858, spurred Lapham to another effort in behalf of his favorite project. He wrote to C. J. Brydges (December 31, 1858), president of the railway, quoting Espy's results, and explaining the value of the warnings to the captains of the car ferry. Brydges refused to undertake weather reports on the ground that a cable across Lake Michigan would be required. Lapham then presented the project to Joseph Henry asking that the Smithsonian Institution supply barometers and wind vanes for reporting stations at Prairie du Chien and La Crosse, saying that the telegraph company would transmit the reports free of charge. Henry replied that his finances would permit him to offer nothing more than thermometers for the observers, and mentioned Maury's effort to establish a rival service. The Civil War made any further effort out of the question for the time, but in 1869 the success of Cleveland Abbe in enlisting the support of business men for a telegraphic weather service at Cincinnati encouraged Lapham to make another effort.

Cleveland Abbe (born 1839, died 1916), astronomer, trained by Brunnow at Ann Arbor, and by Struve at Poulkova, had been called in 1868 from the Naval Observatory at Washington to the post of director of the Cincinnati Astronomical Observatory. This observatory, founded in 1842 by Ormsby M. Mitchel, and supported in part by private subscription and in part by Mitchel's writings and lectures, had fallen into desuetude during the Civil War. Abbe threw himself with great enthusiasm into the rehabilitation of the observatory but quickly found both the building and the site unsuitable. A new site had been offered, and it was with the object of maintaining public interest and support pending collection of funds for a new building that Abbe turned to meteorology. In the end the delay proved fatal to Abbe's prospects. The supporters of the observatory became interested in founding the University of Cincinnati. The grounds of the old observatory, in which the Longworth family held a revisionary interest were sold for $50,000 and the money given to the university fund. Interest in the observatory temporarily fell off, and with it the income of the astronomer, so that by the end of 1870, Abbe, who had just married, was obliged to search for more lucrative work. The new site and the astronomical instruments were then turned over to the new university but astronomical work was not resumed until 1873.

The first communication from Abbe to Lapham was an invitation dated August 9, 1869, to attend a meeting to organize a meteorological association. This was followed on August 29, 1869, by a letter saying that the Chamber of Commerce of Cincinnati had requested Abbe to publish a daily weather bulletin, and asked on what terms Lapham would furnish reports from Milwaukee. Lapham induced the Milwaukee Chamber of Commerce to defray all expenses of reports from Milwaukee, but as Lapham lived too far from the telegraph office, Louis E. Levy was engaged to make the observations under Lapham's supervision. Abbe acknowledged this in the following letter:

CINCINNATI, *October 15, 1869.*

DEAR SIR: The many demands upon my time have forced me to delay writing you, as I would like to have done, to thank you for your kind interest in our observatory weather bulletin. This latter is meeting with much favor and I hope soon to be able to send copies of it to our correspondents.

At present I must confine this note to a short request that you will please instruct the gentleman who sends me his daily observations to send me only the 7 a. m. observation and to send it so early that I may be sure of getting it before 10:30 a. m. of the same day. It should, if possible be delivered to the telegraph operator before 9 a. m.

The messages that I have received contain the three observations of the day and are received at 10:30 a. m. of the following day at which hour I visit the telegraph office and compile the daily bulletin The observations of the previous day have then lost much of their interest.

I trust that it will not much add to the voluntary labors of your friend, my correspondent. If this early transmission be incompatible with his duties I will endeavor to secure the services of the manager of the telegraph office.

I am much indebted to you for a copy of your interesting article on the meteorology of Lake Michigan, etc., which I have perused with interest.

I have the honor to remain,
Very respectfully yours,

CLEVELAND ABBE.

Hon. I. A. LAPHAM.

P. S. Please begin each dispatch with the name of the day of the week on which the observation is made and request the writer to sign his name.

C. A.

One day in November, 1869, Lapham met E. D. Holton on the street and learned that he was going as delegate to the annual convention of the National Board of Trade (now Chamber of Commerce of the United States) at Richmond, Va. While talking with Holton, it occurred to Lapham to renew his efforts for a storm warning service for the Great Lakes. He explained the matter to Holton, and asked him to put the matter before the convention. Holton agreed, provided Lapham would prepare a formal resolution embodying his plan.

On December 1, Lapham wrote Abbe that "a friend will call the attention of the National Board of Trade to the importance of storm warnings." Lapham's resolution was introduced by Holton at Richmond on December 3 (**5**) was referred to the executive council, and reported out by Chairman Hazard with an added clause "to recommend to Congress to afford such aid to the different observatories of the country as will enable the astronomers in charge to give necessary time to the subject." Lapham afterwards surmised that this was written by the delegates from Cincinnati, of whom John A. Gano (president of the Cincinnati Chamber of Commerce) was nember of the executive council at Richmond. This episode of the Richmond convention was fruitless simply because the executive council did not meet again until March, 1870, to prepare the memorials of the convention for presentation to Congress (**6**, p. 6 and 12), by which time Congressman Paine, from Milwaukee, acting on other representations from Lapham had already procured the passage of the desired legislation. Holton's claim (**7**) that he immediately forwarded the resolution of the convention to Congressman Paine is belied by its absence from the memorials that Paine had printed in the Executive documents.

That Abbe was not aware of the Richmond resolution is indicated by the following contemporaneous letter:

CINCINNATI, *December 4.*

MY DEAR SIR: I am indebted to you for two highly esteemed letters with valuable inclosures. The former should have been answered long since but that my time has been so completely occu-

pied by the daily recurring duties of my position that all correspondence has been postponed now for the past five months.

I shall surely make an appropriate return for your very highly valued photograph as soon as I have some of my own taken.

Your essay on the meteorology of the lake country was too intimately connected with my own studies not to attract my immediate attention.

Although not professing to know much of meteorology yet I have undertaken the preparation of our daily weather bulletin as a means of starting what I esteem to be a highly important enterprise.

The three months' trial are not at an end and the chamber of commerce of this city who have liberally defrayed the incidental expenses of the same are now of the opinion that it is able to sustain itself (with the support of the daily press of this city).

Negotiations are now in progress which will doubtless lead to the call of an able meteoroligist to take charge of this matter and the attempt to forewarn important ports of approaching storms will be inaugurated and pushed systematically.

I hope that I shall thus in a few months be able to return to my proper study—astronomy—and to extend the labors of the observatory in that direction.

At present we are unable to do anything satisfactorily because of our ill-constructed building and exposed situation.

Your list of disasters on the Lakes is a sad picture and it should be the earnest endeavor of all scientists so to obtain that knowledge as to avert such calamities.

I return your barometric curve after having entered by date the observations made at this observatory during that time (recorded in local mean time), the comparison of the curve will have some interest to you. It is to be regretted that Thanksgiving Day somewhat interfered with the labors of myself and two faithful assistants.

With high respect I remain,
Very truly yours,

CLEVELAND ABBE.

HON. I. A. LAPHAM.

Abbe gives the following history of the Cincinnati bulletin in his annual report as director of the Cincinnati observatory, dated June 4, 1870:

The bulletin began September 1, 1869, in a manuscript form. Since December 1, 1869, independent publication was discontinued and the bulletin only appeared in the morning papers. A daily compilation was undertaken two weeks ago (i. e. May 20, 1870) by the Western Union Telegraph Co. and will so continue thus relieving the observatory of all further responsibility.

Soon after Holton left for Richmond, Lapham mentioned his project for telegraphic storm warnings to Mr. C. W. Jenks, editor of the Bureau, a commercial journal published monthly at Chicago to which Lapham had contributed articles. Jenks asked Lapham to write an article on the subject. This appeared in the January, 1870, issue and contained the suggestion that the weather service should be established as a department of the Chicago Academy of Science (of which Lapham had been member, and chairman of geology, since its beginning). This reference to the academy has been misinterpreted by Abbe (8) and Weber (9). William Stimpson, president of the academy, received the suggestion cordially, writing Lapham, February 1, 1870, "we hope that such a bureau of the academy may be established and we are doing all we can toward it. May we hope that you will come to Chicago and take charge of it." The Chicago Tribune (January 8, 1870) ridiculed the proposal, saying:

The January number of the Bureau is out and as usual is devoted to questions of finance and commerce. A rather curious feature of this number is an article in favor of establishing a meteorological department in the Academy of Science. The article is accompanied by a map purporting to show the origin and progress of the storm of March 14–17, 1859, and that it might have been known on the Lakes a whole day before it reached there. It might be asked of what practical value such a department would prove it if takes 10 years to calculate the progress of a storm.

Jenks, editor of the Bureau, proposed a stock company with capital stock of $200,000, and asked Lapham to accept the presidency.

On December 8, 1869, the Milwaukee Sentinel published a list of 1,914 vessels, valued at $4,100,000, that had been lost on the Great Lakes in the year 1869, with loss of 209 lives of sailors and passengers. This reminded Lapham of his memorial to the legislature in 1850, so he prepared a formal memorial to Congress in the following terms:

Not only does the interest of commerce and navigation, but also that of humanity itself, demand that something be done, if possible, to prevent the fearful loss of life and property on our Great Lakes, such as has recently filled so many newspaper columns with their appalling details.

If we could have even a few hours' notice of the approach of the great storm that bring these calamities upon us, much of their mischief would be avoided. The endeavor to predict the occurrence of storms has been attempted in England, by the late Capt. Fitz Roy, and in France by Le Verrier, the astronomer, with what success will appear from the following extracts:

"On the 2d of December, 1863, I received two dispatches stating that a severe storm was about to traverse France" writes the president of the Toulon Chamber of Commerce to M. Le Verrier. "They were published and posted up immediately and the merchant vessels in the roadstead had time to provide and did provide against all risks. The maritime prefecture, on its behalf, directed all officers, who were on shore, to hasten on board their vessels. The storm burst forth with all its fury about 3.30 o'clock in the afternoon. The first telegram sent on the 2d confirming that of the day before, had therefore gained four hours time ahead of the storm, and everything was ready to meet the emergency. Thanks to the precautions thus taken there was no damage, no disaster to deplore."

The Genoese Journal of December 3, says that the "prediction telegraphed by the Paris observatory to turin, and immediately communicated to the ports on the western coast of Italy, on the 1st instant was fully realized. The first signs of the storm were felt yesterday about 7.30 p. m. During the night it raged furiously, but there appears nevertheless to have been no disastrous occurrence in our neighborhood. The commandant of the port had hastened to take all proper measures and we may be thankful for them."

Prof. J. P. Espy, in his second report on meteorology makes among many others the following generalizations from the observations made and collected up to the year 1850, the date of the report: "Storms in the United States travel from the west toward the east. They are accompanied with a depression of the barometer near the central line of the storm. They are generally of great length from north to south, and move side foremost toward the east. Their velocity is such that they travel from the Mississippi to the Connecticut River in about 24 hours and from thence to St. John's, Newfoundland, in nearly the same time, or 36 miles per hour, and the force of the wind is in proportion to the suddenness and greatness of the depression of the barometer."

Subsequent observations have fully confirmed the truthfulness of these important deductions, which may therefore be set down as established facts or principles in meteorological science. The storm of March 22, 1861, is known to have occupied eight hours in passing from Dubuque on the Mississippi to Milwaukee on Lake Michigan.

Now it is quite clear that if we could have the services of a competent meteorologist at some suitable place on the Lakes with the aid of a sufficient corps of observers with compared instruments at stations located every 200 or 300 miles toward the west, and the cooperation of the telegraph companies, the origin and progress of these great storms could be fully traced, their velocity and direction of motion ascertained, their destructive force and other characteristics noted—all in time to give warning of their probable effects upon the Lakes.

Doubtless there would be failures and mistakes made; and many experiments and repeated observations would be necessary before the system could be made to work with perfection. But is not the object sought of sufficient importance to justify such a sacrifice? If it should prove successful in even one case, it might be the means of saving property worth many times the cost of the experiment.

But how shall all this be accomplished and who will assume the burden of its cost. Perhaps the establishment of a meteorological department of the Chicago Academy of Sciences with a proper organization and a sufficient endowment would be the most likely to secure the desired results. The money should come from those most likely to be benefited.

This memorial, with clippings of the list of marine disasters, was forwarded in the following letter:

MILWAUKEE, WIS., *December 8, 1869.*

DEAR SIR: I take the liberty of calling your attention to the accompanying list of disasters to the commerce of our Great Lakes during the past year, and to ask whether its appalling magnitude

does not make it the duty of the Government to see whether anything can be done to prevent, at least, some portion of this sad loss in future.

Yours very truly,

I. A. LAPHAM.

Hon. H. E. PAINE, M. C.

By the rarest coincidence, Paine had studied under Elias Loomis at Western Reserve College, Ohio, when the latter was making his pioneer studies of storm structure and movement. Paine therefore fully realized the importance and the practicability of a storm-warning service. On December 14, 1869, he obtained permission to print the papers from Lapham as congressional documents (10) and two days later introduced his bill (H. R. 602) providing for the establishment of a storm-warning service. This was read twice and referred to the Committee on Commerce (11). As soon as copies of his bill and the Lapham memorial came from the Public Printer, Paine sent copies to the heads of the two existing weather services, Surgeon General J. K. Barnes and Joseph Henry, secretary of the Smithsonian Institution, and to his old professor, Elias Loomis, at Yale College. In an account of these incidents (12) Paine afterwards wrote "Immediately after the introduction of the measure, a gentleman called on me and introduced himself as Col. Albert Myer, Chief Signal Officer. He was greatly excited and expressed a most intense desire that the execution of the law might be intrusted to him." Paine gave Myer a copy of the bill and of the documents. Responses from Barnes, Henry, Loomis, and Myer were printed at Paine's request as congressional documents (13). For some reason, Paine rewrote his bill, and with the cooperation of Senator Henry Wilson (elected Vice President of the United States with Grant in 1872) introduced it as a joint resolution (H. R. 143) on February 2, 1870. This passed both houses, and was approved by the President in only one week. This speed not only anticipated the action of the executive council of the National Board of Trade on the Lapham resolution, but even the Committee of the New York Chamber of Commerce did not get around to recommend extension of the scope of the first Paine bill until March 17, 1870 (14) John D. Jones, who had proposed a commercial weather service in 1848 was member of this committee.

The rôle of Cleveland Abbe in these events is clearly shown by the following letter, the original of which like those previously quoted is in the collections of the Wisconsin Historical Society.

CINCINNATI OBSERVATORY, *January 7, 1870.*

DEAR SIR: I must write to express the pleasure experienced in realizing the energy with which you are pushing the matter of a telegraphic meteorological system of storm warnings.

My own labors in this field have been not perhaps so much for the good of the country and the advance of meteorology as for the sake of astronomy.

We can, I think, make no more progress in our knowledge of terrestrial and celestial refractions until we better understand the laws of distribution of heat and pressure in the atmosphere and our proposed system of signals coupled with a daily bulletin or chart will much help the study.

My additional incentive has been the desire to inform the community in general with the usefulness of the work carried on at observatories. To this end I have endeavored to expand the field of activity of the observatory so as to include meteorology, magnetism, geodesy, geography, and all other matters kindred with astronomy.

By pursuing this course it seems as though we might hope to place upon a sure foundation the establishment of a few good observatories which should combine the usefulness of Greenwich and the science of Poulkova.

I trust that in this view you will coincide or at least that it will not be opposed to the principle that may have guided you. Astronomy especially has suffered in this country from dissensions and the observatories have been weak and poorly appreciated. We must seek to secure the support of the people by demonstrating our usefulness.

I have in the Smithsonian report for 1867 shown the course pursued by Struve and its results. He may well be accepted as a model in this respect.

I write with the more feeling because I have noticed the introduction of a bill in the United States Senate recommending the appropriation of money to the Army for the purpose of carrying on the system of storm warnings.

Now these warnings ought to be based upon observations made by the intelligent telegraph operators or managers of offices or other employees. The meteorological observations of the Army have generally proved themselves very unreliable and are certainly no better than those that the telegraph operators could easily make.

It would, I think, have been wiser if the bill had recommended that Congress appoint a committee of three (Henry, Coffin, and a naval or Army officer) to report some plan of action.

And I am specially of opinion that the money expended would do more toward effecting good results if it goes through the hands of meteorologists than through the hands of Army officers.

It would be a pity to see the country saddled with an inefficient meteorological office as it has already enough to do to carry on the naval observatory with its present objectionable system of management. Every such onus is a hindrance to the progress of science in this country.

I presume, however, that we shall both be able to unite upon some plan that will prove feasible.

I beg to thank you again for the copy of the Bureau containing the map of the storm of 1859, March 14. The daily weather bulletin that I have been publishing stops temporarily but will be resumed. I have sent a short notice of it to the Bureau.

Very respectfully yours,

CLEVELAND ABBE.

Hon. I. A. LAPHAM.

Paine afterwards wrote that his "reason for requiring the Secretary of War to execute the law was this: It seemed to me at the outset, military discipline would probably secure the greatest promptness, regularity, and accuracy in the required observations." The economy of having the work performed by the Army, whereby all expenses for pay, subsistence, quarters, and travel of officers and soldiers were borne by the usual appropriation for the Army, and the only additional expense was for telegraph tolls, stationery, instruments, pay of civilians, etc., doubtless facilitated the passage of the act. The initial appropriations were $15,000 for the remainder of the fiscal year ending June 30, 1870, $50,000 for the next fiscal year.

The Secretary of War promptly assigned the meteorological duties to the Chief Signal Officer of the Army, Brevet Brig. Gen. Albert J. Myer, who christened the new activity "the Division of Telegrams and Reports for the Benefit of Commerce." General Myer had entered the Army in 1854 as assistant surgeon. While serving with troops in New Mexico he observed Comanche Indians signaling with their lances, and devised therefrom the now familiar code of wigwag signals with flags and torches to replace the couriers then in vogue as the sole means of military communication. In 1860 Myer was appointed signal officer of the Army to develop his system. The Civil War brought a huge expansion of the Signal Corps, as part of the volunteer army. In 1863 Myer became involved in controversy with the Superintendent of military telegraph over control of field telegraph lines, with the result that he offended Secretary Stanton, was relieved from duty and sent to Cairo awaiting orders which never came. His appointment ran out July, 1864, and he was out of the Army for nearly three years. Lieutenant Colonel Nicodemus succeeded to Myer's place, and his quarrel, with the result that he was summarily dismissed from the Army December 26, 1864. Maj. B. F. Fisher, next in command, more diplomatic, carried on and was nominated, February 13, 1866, by President Johnson to be Chief Signal Officer, and was confirmed by the Senate. Myer's friends then

melodramatically came to the rescue, induced the Senate to recall Fischer's confirmation, and in 1867 procured the appointment of Myer with pay of colonel, from July 28, 1866, rank of Brevet brigadier general, and commendation for gallant and meritorious conduct in organizing, instructing, and commanding the Signal Corps. He had previously won congressional commendation for bravery in action. However, the Signal Corps had been mustered out with the volunteer army in 1865, and the Army reorganization act of 1866 had specified that under the Chief Signal Officer the duties of signaling should be performed by not to exceed 6 officers and 100 men, detailed from the Corps of Engineers. It is on this account that Myer was spoken of as a bureau chief without a bureau. It also resulted in his bureau being referred to by a variety of names, Signal Service, Signal Corps, Signal Office, Signal Detachment, Signal Force, Signal Bureau. The estimates for 1870–71 (**15**) for his establishment consist of the following items:

	Pay	Subsistence	Clothing	Total
Chief signal officer	$1,320	$657		$1,977
2 servants, enlisted	384	219	$156	759
2 clerks, class 2	2,800			2,800
Total				5,536

His troops had been practicing with salvaged war material in the abandoned forts, Greble and Whipple (the latter now Fort Myer), but the estimates just mentioned contain the first postwar request for funds for the purchase and repair of electric telegraph and signal equipment for the Army. Myer asked $10,000 but the Secretary reduced it to $5,000 over Myer's protest, which was printed in the estimates.

Myer's excitement, mentioned by Paine, can be set down to a just appreciation of the possibility of directing another growing institution like the war-time development of the Signal Corps.

Myer's first meteorological report for 1870 shows him busy enlisting and training observers, buying instruments, negotiating with telegraph companies, and renting offices. He sought advice from G. W. Hough, of the New York Meteorological Service, and from Balfour Stewart at Kew Observatory, also from the Smithsonian Institution, Coast Survey, Naval Observatory, Commissioner of Agriculture, Surgeon General, and the Cincinnati Observatory.

Apparently, Myer hoped to get along without forecasters, for he writes (**16**):

> The publication of official deductions or forecasts to be had from the mass of reports received at different centers involves so much of responsibility, that, while it has been considered, the office has not been willing to enter upon it, until it shall have practically tested the promptness with which reports will be received, and the facts as to the approach and force of storms which synchronous reports following each other in close succession will announce without any effort of anticipation.
>
> It has been considered wise by this office not to attempt more than this at the outset.

However, the new service was not ready to begin telegraphic reports until November 1, 1870, in the midst of the season of storms on the Great Lakes. Under these conditions Myer must have suddenly changed his mind, for he telegraphed Lapham to meet him at Chicago on November 8, 1870. There he tendered and Lapham accepted appointment as Assistant to the Chief Signal Officer at a salary of $167 per month, to supervise the signal service on the Lakes. Appointment and orders were written out in Myer's own handwriting and are in Lapham's papers. Myer must have felt that the situation admitted no delay for Lapham issued the first storm warning on the day of his appointment. The selection of Lapham may have been influenced by Paine. The Lapham papers contain a note dated October 13, 1870, from Paine, then in Milwaukee, asking Lapham to call at his office, as he wished to communicate with him about storms.

Lapham necessarily began forecasting with no previous experience, and with only what information could be gleaned from the publications of Redfield and Espy, Loomis's Meteorology (of these Lapham's personal copies, are now in the library of the University of Wisconsin). It is worthy of note that Lapham used isobars and isotherms on his forecast maps at Chicago (**17**), while the Washington forecast maps, begun January, 1871, imitated the Cincinnati bulletin in omitting these lines. The difficulties of forecasting must have seemed overwhelming at times. On November 23, 1870, Lapham left suddenly for Milwaukee asking that all telegrams be sent to him there, explaining that it was necessary for him to have access to his library. Captain Pyne, acting Signal Officer, replied that the post of assistant could not be changed to Milwaukee, asked Lapham to move his books to Chicago, and expressed the hope that no detriment to the service had occurred on account of Lapham's absence. The complete net of reporting stations numbered only 25, and on one occasion a storm reduced the number received to four. The observer sergeants had been supplied Guyot's Tables and left to their own devices to reduce the barometer to sea level at each observation. The results were so chaotic that Lapham had to set to work in the midst of forecasting to prepare uniform reduction tables for each station. Meantime, there were other irritations. On December 20, 1870, Capt. Garrick Mallery called attention to an error in his official signature The title "Assistant Chief Signal Officer" which Lapham has used was "liable to misconception" and "might cause criticism in the War Department." Lapham recommended appointment of his son Henry as observer at Milwaukee, and was asked by Mallery if he wished Henry to enlist in the Signal Corps and be assigned as observer sergeant to Milwaukee. The Laphams being Quakers this suggestion was not available. Then, Lapham's many business interests at Milwaukee left at loose ends by his sudden appointment, demanded his attention so that he was obliged to ask (December 26, 1870) to be allowed 2 days a week at Milwaukee, and offered to resign his post if it could not be arranged. Then his friend Kilbourn died, naming him executor. Lapham took leave of absence in January, 1871, to go to Florida to look after lands owned by Kilbourn, and on his way back visited Washington, whence he wrote his daughter:

> Washington, D. C., *February 3, 1871.*
>
> Dear Julia: I dined last evening with General Myer at his home on I Street. Have arranged matters satisfactorily—am not to be ordered to Chicago any more.

This arrangement, however ideal for Lapham, could not have been satisfactory to General Myer, whose appropriation of $50,000 for the year 1870–71, $102,451 for 1871–2, was quickly swallowed by rapidly increasing demands for service to the public. However, Lapham was allowed to live at Milwaukee and to devote himself to the leisurely preparation of a report on atmospheric electricity, to collection of statistics on the frequency of storms and of the disasters on the Great Lakes. The great fires of October 8, 1871, of which the Chicago fire is the best known, while the Peshtigo fire in the Wisconsin

forest destroyed many more lives, also formed the subject of an official report from Lapham's pen. He visited the observer at Chicago the day after the fire, and finding that his reduction tables had burned, supplied new ones from his own copy. The termination of this arrangement came in the following form:

WASHINGTON, D. C., *May 11, 1872.*

Dr. I. A. LAPHAM,
Milwaukee, Wisconsin.

DEAR SIR: I am directed to inform you of the limited amount of money at the disposal of this office for the current year and the consequent necessity for the reduction of its working expenses. The arrangement by which your valuable services have been secured as Assistant to the Chief Signal Officer will terminate at the close of the present month.

It is hoped that the office will be in sufficient funds by that date to liquidate your account in full.

Respectfully,

H. W. HOWGATE,
Captain, and acting Signal Officer.

Of Lapham's later career it will suffice to mention that as chief geologist (April 10, 1873, to February 16, 1875) he organized and energetically directed the Wisconsin Geological Survey. He was beginning an investigation of temperatures and other conditions in the inland lakes of Wisconsin, with reference to fish production, when he died of heart failure while in a boat on Lake Oconomowoc, September 14, 1875.

Beginning January, 1871, Myer organized at Washington a corps of forecasters consisting of two civilians, Cleveland Abbe and Thompson B. Maury, and one officer, Lieut. A. W. Greely, and made them responsible for forecasting for the entire country. Maury afterwards joined the staff of James Gordon Bennett's New York Herald, for which he wrote a daily column of weather information published on the editorial page under the unique title "Personal Intelligence." Greely led the tragic *Lady Franklin Bay* Arctic expedition of 1881–1883, one of the two expeditions for meteorological observations that Myer had undertaken as America's share in an international attack on the problems of Arctic meteorology. Greely succeeded to the place of Chief Signal Officer, March 3, 1887, and remained in command of the Signal Corps when the Weather Bureau was separated in 1891. Cleveland Abbe occupied throughout his life the position of dean of the scientific staff of the National Meteorological Service and is probably best known as editor of the MONTHLY WEATHER REVIEW, and of three volumes of papers on the mechanics of the earth's atmosphere published by the Smithsonian Institution.

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ANTARCTIC METEOROLOGY

By HENRY T. HARRISON

[Weather Bureau, Cleveland, Ohio]

The title "Antarctic Meteorology" may seem misleading and rather presumptious. To even begin to cover so vast a subject in a limited paper is of course out of the question. However, it is the aim here to present (1) only the general features of prevailing conditions, as now known, existing over the continent as a whole, and (2) to describe in detail some of the results of a 15 months series of observations made in one locality.

It appears to be fairly well established now that Antarctica is in the waning stages of one of the severest ice ages ever known. Save for bare rocky outcrops and bare sharp peaks the entire continent lies buried beneath the accumulation of centuries of snow and ice ranging upward to an estimated depth of several thousand feet on the polar plateau itself. Surrounded on all sides by the comparative warmth of ocean water, the cold continental air is constantly being mixed with violently opposed air masses from over the seas. Acting as a huge refrigerator the continental ice cap not only produces a steep temperature gradient in winter but maintains it to a lesser degree even during the short summer season. Add to this turbulent influence the typical glacial action of producing local but violent "fall" winds and we have the basic reasons for the unusual atmospheric activity over most of Antarctica, the stormiest area in the world. Sir Douglas Mawson aptly named it "The Home of the Blizzard." At his winter base in Adelie Land south of Australia hurricane winds were of almost daily occurrence and occasional gusts neared a velocity of 200 miles per hour.[1] Captain Scott and Sir Ernest Shackelton experienced very nearly the same winds although interspersed with a far greater proportion of calms at McMurdo Sound near the western edge of the Ross Sea.[2] Little America and the Bay of Whales region are comparatively free from violent hurricane winds although just 100 miles to the east at the foot of the Rockefeller Mountains the geological party of the Byrd Expedition experienced one storm during which the wind reached an estimated velocity of 150 miles per hour. The oceans surrounding Antarctica are generally recognized as being the stormiest waters in the world. The extreme local nature of many of the storms has been proven time and again. After the aforementioned Rockefeller Mountain hurricane there were evidences that little more than a moderate gale had prevailed just a few miles away while, at Little America, the same storm produced a wind of only 50 miles per hour (22.4 m. p. s.). Mawson and his party in Adelie Land found the almost unbe-

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

lievable combination of a strong gale and a light breeze prevailing side by side within the limits of a few miles.[1]

At widely scattered intervals but especially during winter great cyclonic storms develop somewhere near the rim of the continent and are attended by severe blizzards over a wide area. Definite paths of these cyclones remain unknown although one well defined track appears to lie along or near the Antarctic Circle with general movement from west to east. Professor Hobbs holds to the theory that a great glacial anticyclone covers the interior of the continent and this view is shared by others although as yet no definite conclusions may safely be drawn because of the scarcity of available data. Only scattered and irregular observations have been made on the polar plateau during two of the summer months and winter conditions there are absolutely unknown. Another theoretical distribution of pressure places an anticyclone over the polar plateau and, surrounding it, a series of cyclone centers which move in unbroken succession from west to east along the outer edge of the continent. The normal drain of air is from the pole outward toward the sea at the surface but, due to deflection by the earth's rotation, winds become easterly or southeasterly near the oceans. Theoretically this outpouring of air at the surface would be offset by an inflow at higher levels of air from lower latitudes. Pilot-balloon soundings bear out this theory for the most part although many instances have occurred where winds were from the south up to altitudes of 4 miles (5,000 meters) and occasionally even into the stratosphere.

Due to excessive cooling near the ice surfaces sharp inversions of temperature prevail at low levels aloft during periods of calms or light winds; hence the blizzard winds, which actually blow from the colder interior, are almost invariably attended by rapidly rising temperatures at the surface as a result of the mixing of the two layers of air. Evidences also show that many of the blizzards, expecially those in the Ross Sea region, are simply relief valves by means of which enormous masses of cold air which pile up in the interior are dumped over the sea, somewhat in the manner of the working of a hydraulic ram. During the expeditions of Scott, Shackelton, and Byrd it was noted that any protracted period of extreme cold on the Ross Barrier, or Ice Shelf as it is now known, was invariably followed by a severe blizzard at the edge of the Ross Sea. Once an initial release was given to this sluggish mass of dammed up air—and this could be accounted for by a weakening of pressure in the Ross Sea—a violent outpouring would result for a day or two until equilibrium was once again established. Simpson [2] points out that a semipermanent area of relatively low pressure prevails over the Ross Sea as a result of the steep temperature gradient maintained in that region and that even a slight strengthening of the pressure gradient would be sufficient to supply the initial energy for the release of a blizzard.

Little America was the base camp of the Byrd Antarctic expedition from December, 1928, until February, 1930, and was established on slightly rolling slopes of the Ross Barrier at the Bay of Whales in the southeastern corner of the Ross Sea. The ice shelf in this region is floating in salt water with the nearest visible land and also the nearest known land lying 100 miles to the eastward. Pilot-balloon soundings and detailed surface observations were made daily over this 14-month period while soundings of the upper air by means of kites were made during the final season.

A smooth recording of data was beset with many difficulties, most of which could be traced to the weather itself, wind and cold. Because of their relative importance the pilot-balloon soundings were begun back in the early stages of the camp during the bustling days of unloading, sledging and snow-shoveling. At that time everyone was working from 12 to 15 hours each day in an effort to get the camp firmly established before winter set in, yet sufficient spare time was found each day to make at least one observation of the upper air currents. The balloons were inflated inside a tent and the readings made with a theodolite placed on the surface of the barrier, exposed to wind and cold. A succession of blizzards in February and March kept the instrument snowed under constantly so that it was necessary to shovel it out before each observation. Toward the end of April, however, attention was given to the building of a permanent shelter and stand adjoining the vestibule of the administration building with a telephone connection with the scientific room inside the house, thus doing away with the necessity of recording data outside in the cold. Because of the danger from fire inside the house the balloons were inflated with hydrogen in the tunnel exit of the house where the temperature averaged 40° below zero and this fact alone was the cause of more than one ruffled disposition. As the dark winter came on and the temperature dropped still further the lens and eye-piece of the theodolite were subjected to thick accumulations of rime frost until it became necessary to scrape off these coatings with a small stick every minute or so during observations in order to avoid losing sight of the balloon. Occasionally frost formed on the inside of the lens and whenever this happened the instrument had to be taken inside the house and thoroughly "baked out" over the stove. The small paper lanterns used in the night work were another source of worry. Unless well heated beforehand the tallow candles would refuse to burn properly in the cold and frequently went out entirely after the balloon was released. On one occasion five balloons were released before one continued to burn properly; consequently there was more than one reason for rejoicing when the sun returned to Little America in August and the lanterns and lights could be discarded. After a suitable combination of headgear, footgear and gloves had been worked out by experiment little discomfort was experienced in observing the balloons during the coldest weather of mid-winter when the temperature sometimes fell as low as −70° F. (−57° C.) Four hundred and fifteen soundings were made during the 14 months to an average altitude of almost 3 miles (4,500 meters). Curiously enough these observations furnished practically the only basis for making predictions of coming conditions for flight and camp activities. Generally speaking a deep southerly current aloft attended or preceded settled clear conditions and good visibility whereas northerly winds aloft were nearly always associated with thick overcast skies and low visibility. Attempts to interpolate general pressure distribution from local wind and barometric changes were so disappointing that nearly all forecasts were made on the basis of the prevailing upper winds and the assumption of their importation as air masses of varying degrees of temperature and moisture.

The kite work received an early setback when a large crate of parts was lost during one of the blizzards which swept over the camp in March. Replacement was impossible at that time and so it was late in the winter before enough spare parts could be made up to permit assemblage of the kites. For this purpose construction was begun on a large house of snow blocks with one end partitioned

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

off into a work room and the remainder serving as storage space. Interrupted by a 50-mile blizzard which blew down three of the main walls in a mass of ruin, the work was finally completed, the house roofed over with canvas supported by bamboos and a small blubber stove constructed for heating the work room. On a cold day outside the stove would raise the temperature inside the house to about 0° F. (−17.8° C.), just enough to allow bare handed work on the joints and wrappings of the kites. It was in this manner that these structures, of the Marvin-Hargraves cellular type, were set up and made ready for service. The first flight was begun on a particularly cold and disagreeable day in September when working conditions outside were anything but pleasant. After four men had been frostbitten about the hands and face before the flight was finished there was nothing to do but postpone further action until the arrival of more moderate weather. Flights were made with fair regularity during the next three months but were limited in altitude due to failure of the motor driven reel and the necessity of resorting to hand reeling. The prevalence of low stratus clouds during a majority of the flights resulted in quite heavy deposits of hard rime upon the kites and wire, great enough on several occasions to force the kites down, to the surface. These deposits, while not strictly ice were layers of very closely packed frost crystals which built up on all windward surfaces of kites and wire sometimes to a thickness of 3 inches (7.7 centimeters) during the course of several hours exposure in the subcooled clouds. The fact that rime formed on every occasion when kites entered clouds is significant in that it points out a very evident danger which attends the use of dirigibles in polar latitudes. Aeroplane flights at Little America were made only when the sky was clear and so no opportunities were offered for the study of ice formation on heavier-than-air craft.

Fog, while infrequent, was important from the point of view of demonstrating that water vapor can exist in a subcooled state in nature at temperatures far below the freezing point. On one occasion fog formed at −30° F. (34.4° C.) which was dense enough to obscure objects at a distance of 1,000 feet (300 meters). Lighter fogs were observed at −40° F. (−40° C.) but below this point the water vapor ordinarily gave away to a haze of floating ice crystals. Subcooled fog was also attended by a formation of rime. On June 11 a combination of fog and misting rain at a temperature of 5° F. (−15° C.) resulted in the formation of a fringe of rime as much as 4 inches (10.2 centimeters) in thickness on the windward surfaces of all exposed objects. The mist was first attended by a thin coating of glaze before rime began to form. This fall of rain in the dead of winter implies that an enormous temperature inversion existed somewhere above the base of the stratus clouds, a fact which can be explained by the prevalance of northerly winds aloft at the time. These winds were warmed by passage over the open water of the Ross Sea and possibly originated as far north as the Pacific Ocean. Precipitation in the form of snow was almost impossible to measure due to the heavy drift which accompanied most falls. Careful estimates, however, placed the annual snowfall at 103 inches (262 centimeters) which is in fair agreement with figures reported in the McMurdo Sound section. Sleet was unknown at Little America.

Cloudiness and relative humidity averaged high whenever the Ross Sea was open which is to say during most of the year. The two forms of overcast sky, peculiar to polar regions, "ice blink" and "water sky," were of frequent occurrence. The former is the milky, suffused glow upon clouds over snow and ice and the latter the pronounced dark reflection upon clouds over water. Standing on the barrier and looking to the north the sky presented a dark threatening appearance while overhead the sheet of stratus cloud was simply a milky gray blur devoid of all form. On days of this type the outlook was gloomy and discouraging indeed. No horizon was visible except to the north, a murky haze filled the air and, in the lack of contrasting shadows, it was impossible to distinguish any form in the snow at one's feet. Walking about on the rough snow one not only had difficulty maintaining a balance on the uneven surface but the strain on the eyes was often greater than that during the glare of bright sunlight. Ordinarily the line between the water sky and the ice blink was so marked that the edge of the barrier was perfectly outlined on the cloud layer above. Whenever scattered ice floes invaded areas of open water a mottled reflection upon the clouds resulted. In marked contrast to these dull depressing days the sky was often beautifully clear and presented a wide range of colors and delicate tints when the sum was low. Brilliant solar and lunar halos, parhelia, coronæ, the aurora and weird mirage effects—all of these played their part in breaking up the monotony of an everlasting white landscape.

The thermograph and hygrograph, self-recording instruments in the shelter outside, furnished a disagreeable duty once each week when the record sheets were changed. Both instruments were carried inside a tunnel where the temperature was nearly that of the outside air but with the advantage of being protected from the wind. Silk gloves worn during this operation furnished little protection for the hands at −50° F. (−45° C.) but prevented an actual contact with the cold metal of the clocks which would freeze bare finger tips instantly. The clocks themselves behaved beautifully in the cold weather after all trace of oil had been removed from the works with ether. The thermograph did stop when the temperature first touched −70° F. (−57° C.) but after a few minor adjustments were made no more trouble was had with either clock. The fine powdery drift of the blizzard was extremely troublesome through its action of sifting through minute cracks and blocking all movement of the pens. It also built up around the cogwheels with enough pressure to force the clocks off their bases at times. Almost constant attention had to be given to the instruments during the more severe blizzards. The anemometer also suffered in the cold due to an unequal contraction of the brass and steel parts and to the hard gritty layers of rime which formed on the cups. In spite of all of these little handicaps the instruments functioned as well as could be expected under the severe conditions and the records on the whole were consistent and trustworthy.

The severity of the Antarctic cold needs little discussion here. Any climate which can and does produce subzero temperatures (F.) every month in the year is truly frigid and when it combines strong winds with the cold as it often does life in the open is unpleasant indeed. The winter temperatures at Little America were not as severe as those sometimes recorded in the interior of Northern Siberia but the average temperature for the calendar year of −12.7° F. (−24.8° C.) was the lowest ever recorded over a similar period anywhere.[3] The lowest figure during the year was −72.4° F. (−57.8° C.) but a far more severe condition than this prevailed in July when a combination of a 25-mile (11.2 m. p. s.) wind and a temperature of −64° F. (−53.3° C.) was

[3] According to G. C. Simpson (*see* British Antarctic Expedition, 1910–1913, Vol. 1, Calcutta, 1919, page 91, Table 52) Framheim had a mean temperature for one year of −14.4 F., two months being interpolated.—EDITOR.

experienced. Kerosene lanterns froze up at −55° F. (−48° C.) and dry-cell flashlights were rendered useless also. Self-generating dynamo flashlights furnished the only source of light for outside use during the severe cold weather.

In conclusion it may be well to emphasize the fact that there is still an enormous field for meteorological research in Antarctica. Professor Hobbs has long pointed out the great value which would accrue from a year's observations on the polar plateau; such work would be possible although attended with extreme difficulties and hardships to the personnel involved. Simultaneous records at a number of points over the continent are also needed before a really comprehensive and intelligent study may be made of the laws which govern atmospheric action in the southern latitudes. Each expedition has added a bit more to this knowledge yet the field of operations of one or two isolated parties has necessarily been limited. The extent and rapidity of future research hinges, as heretofore, upon the generosity of the people and of organizations in offering financial support for expeditions.

REPORT OF THE STREAM-FLOW PREDICTION SUBCOMMITTEE[1]

By A. STREIFF, Consulting Engineer

[Jackson, Mich.]

The past year was characterized by a greatly increased universal interest in the possibilities of estimating stream flow, which previously has been and, in many professional and scientific quarters, still is regarded as being wholly a fortuitous sequence. During the past decade this viewpoint had gradually undergone a radical change, until to-day many earnest investigators recognize the presence of definite systematic elements in stream flow which permit conclusions to be drawn as to future run-off well in advance of occurrence.

PAST METHODS OF PREDICTION

In the planning of hydraulic projects, the manner of estimating future discharge quantities in the past has rested on a rather questionable basis, untenable on scientific grounds, and dictated by necessity rather than secure, basic knowledge. If stream flow is to be regarded as wholly fortuitous sequence, then the theory of probability is directly applicable to the estimate of future performance. Much has been theorized on future probability (probability a priori) based on past performance or experience (probability a posteriori) or so-called empirical determination of probability. It is a well-established fact that only a voluminous series of data can furnish a secure basis for future expectation. Such data must, moreover, be wholly freed from systematic sequences.

Instead of thousands of observations, hydraulic engineers usually have at their disposal only a few records covering not more than 10 to 50 years. It is evident that 50 dice throws will not give the same average as several thousand, and if systematic changes are introduced, such as changing the throw, the dice, etc., no reliable estimate of future averages based on previous performance is possible. Yet, this is the meager basis on which all hydraulic projects hitherto have been based. The future is held to have the same average, as well as limits of variation, as the past records indicate.

NEW METHODS OF PREDICTION

Certain it is, that stream flow records never repeat themselves, and ceaseless fluctuations exist, continually moving to higher and lower levels apparently in often recognizable systematic sequences. In Europe these have been studied and applied by Dr. Axel Wallen (Twelve Years of Long Distance Prognostication of Rainfall and Waterlevels, Annals der Hydr. und Maritim. Meteorology, September 1926, pp. 89–92), director of the hydrographic service in Sweden. Here, too, much research has been applied to finding a better way of estimating future stream flow. It is the near future which is of the greatest importance in hydraulic power projects, and this may be radically different from the immediate past; enough to create the difference between earned or not earned interest on outstanding bonds.

UTILITY OF PREDICTIONS

Experience of the past 10 years indicates that public utilities which derive their power supply in whole or in part from hydroelectric plants can apply these studies profitably to the appraisal of their future power supply. It appears that for the Great Lakes division it is quite possible to estimate hydraulic power output a year in advance to within 5 per cent. The general trend can be forecast for several years to follow, and thereby the steam power and coal supply requirements can be budgeted more accurately. No errors need be made as by one utility, which constructed an expensive booster pump installation for their circulating water just in advance of the rise in levels of the Great Lakes, or by another in the Great Lakes region, which hurriedly installed expensive additional boiler capacity to take care of threatening shortage just in advance of a rising hydraulic power output.

STREAM FLOW IN GREAT LAKES REGION

The Great Lakes region appears to be distinguished by a singularly regular multiannual sequence of stream flow, which enables close estimates of water power. Naturally such estimates are of greater value, the greater the amount of available storage. Without storage the annual (seasonal) variation determines the requirements of steam power; peak capacity is not affected by a variation of the annual mean, although even in such cases the annual coal supply is still subject to calculation in advance. Members of the Great Lakes division are enabled to utilize the knowledge of these systematic sequences of stream flow in the Great Lakes region to the extent above indicated.

The discovery of this regular cycle in stream flow is due to the hydrologist, Robert E. Horton (United States

[1] Extracted from the 1929-30 Report Hydraulic Power Committee, Engineering Section, National Electric Light Association, Great Lakes division. Presented at the tenth annual convention, French Lick, Ind., Sept. 25-27, 1930.

Geological Survey Water Supply Paper No. 30). Since 1875 the cycle has faithfully recurred 10 times. At present a minimum is approached which will occur in 1931. A further maximum will occur in 1935, and a high maximum in 1940. The hydroelectric companies in the Great Lakes region will profitably note that next year will be a poor water year, and their hydro output will compare with the previous low around 1925.

On the other hand, abundant hydro output will be available in the Great Lakes region around 1934-1936.

STREAM FLOW IN MICHIGAN

For Michigan the graph shown in Figure 1 is illuminating. This graph represents the flow of the Muskegon River in Michigan. It may be seen that the relation with the maxima and minima of the Wolf numbers is striking. This graph was prepared in 1928 and first published in the periodical Power of April, 1929. The dotted line shown thereon is the probable extension of the annual mean stream flow as it appeared to the chairman of this subcommittee in the year 1928. The dotted line drops sharply, indicating dry years in 1930 and 1931. The present drought fully supports the estimate made two years ago. The estimates of power output for the Consumers Power Co. have checked as follows: For 1928, error 5 per cent; for 1929, error 2 per cent; for 1930 the first half of the year exactly corresponded with the estimate.

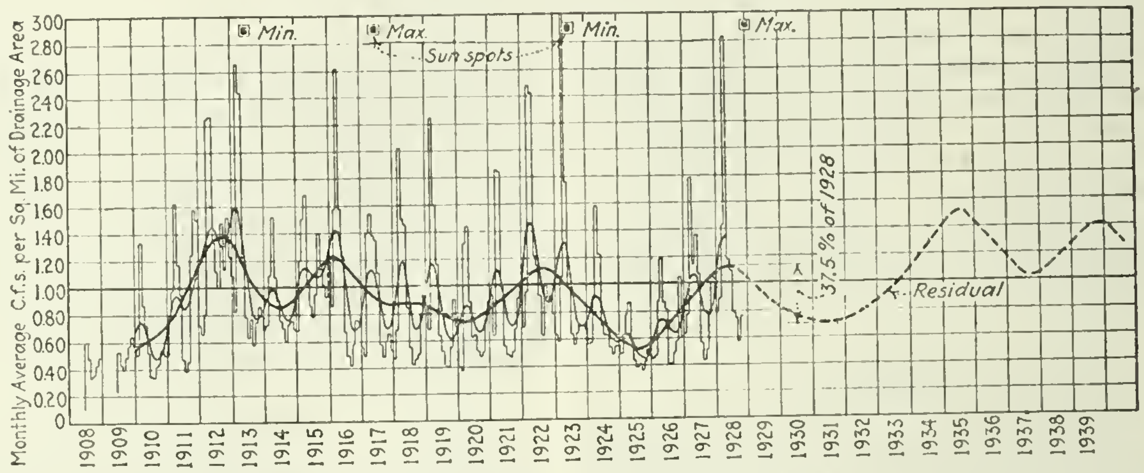

FIGURE 1.—Stream-flow prediction for Muskegon River, Mich.

It should be mentioned that the lower peninsula of Michigan has, on account of its heavy cover of glacial drift, a very great volume of ground storage, which favors the exact realization of these estimates. Next year a minimum output of hydro in Michigan will occur, the deficiency being as high as 37.5 per cent of the 1928 hydro output.

In a personal letter to the editor, Mr. Streiff comments on the methods of stream-flow prediction as follows:

JACKSON, MICH., *January 25, 1931.*

DEAR PROFESSOR HENRY: Hydraulic engineers thus far have been in a quandary. In a continental climate, as that of the United States, the water problem is, for great parts of the country, that of a deficiency. The economics of projects costing millions depend on an accurate estimate of the quantity of water which is available, or will be, in the future. The theory that future averages will be equal to past averages has led to financial failures in a number of cases. I have personally been involved in two of them during the past 20 years.

Hence we have been forced to cast about for other solutions, and while we believe we are on the right path, this is strictly an engineering belief. Engineers are in every branch striding far ahead of scientific certainties and proceed on "opinion," "judgment," "hunch," and so forth. Hydrodynamics is still in a very elementary stage as far as the possibility of computing flow of water is concerned, but still engineers build water turbines of 93 per cent efficiency, largely empirically.

Hence the report should be regarded from that standpoint. It is a technical expedient. I fully disclaim its scientific value. And it should be regarded as wholly in the field of hydraulic engineering. I really feel very little informed about meteorology.

Respectfully yours, A. STREIFF.

A METHOD OF DETERMINING THE ALTITUDE IN THE ATMOSPHERE ABOVE SEA LEVEL WHERE THE FREEZING POINT OF WATER OCCURS

By J. F. Brennan, Government Meteorologist

[Kingston, Jamaica]

There are many devices already in use for registering the temperature, relative humidity, pressure, etc., aloft, such as self-registering meteorographs attached to sounding balloons, which are costly, and some delay is occasioned when recovering these instruments.

It is well known that the property of water is to expand at the instant of freezing by about 10 per cent.

Now, if a short length of copper tubing of about 0.10 inch bore with walls about 0.02 inch thick, be bent in the shape of a horseshoe, as per sketch (fig. 1), then filled with water (preferably distilled), the ends compressed in a vice and soldered, made quite free of air. At the moment of the water freezing the arms A—A will separate over half an inch. Therefore if a ring of metal wire be strung around A—A it will become disengaged at the moment of separation of the arms. A short length of thread F (about 12 inches), is secured to a paper pendant, D, and then attached to the ring B. The upper part of the horseshoe, at C, takes a length of thread, F_2, about 10 feet, to the closed mouth of the inflated pilot balloon E. The curved portion of the copper horseshoe tube, at C, should be flattened (somewhat similar to that of a Bourdon steam gauge), so that the major diameter of the elliptic section will be double that of the transverse diameter. This flattening will, of course, aid to insure suitable separation of the arms A—A.

When all be in readiness the thread F_2 above the horseshoe should be held by the fingers, and not at F_1, for the reason that the free-lift of the balloon is apt to permit the ring B to escape by strain.

At the moment the pilot balloon attains the altitude of freezing of water the pendant D falls away, and the altitude at this moment noted.

Mr. Brennan in his letter to the Weather Bureau adds the following:

Inclosed you will find one of the actual horseshoe copper tubes which was experimented upon, when placed in a freezing mixture of ice and salt. I have exposed quite a number, and the separation of the arms A—A upon the moment of freezing of the water had a maximum expanded space of 1½ inches, when it fractured at the point C on the flattened curve of the tube.

The total weight of the copper tube and pendant used did not exceed 20 grams, but no doubt the device can be contrived to be much lighter if necessary.

It is just possible that much lower temperatures than 32° F. at greater altitudes may be determined by filling the tube with distilled water mixed with a small amount of glycerine, or other suitable soluble substance, whose freezing point is predetermined in the laboratory. Two or three pendants, mixed with different solutions, may be attached to a balloon, so that the temperature gradient up to great altitudes may be secured during a single pilot-balloon ascent.—*Editor.*

Note.—Since the receipt of Mr. Brennan's original communication he has submitted the following:

On January 30 I tried my device with two separate balloon ascents. The first failed on account of entering cloud at low altitude, and the second ascent on February 2 attained an altitude a little beyond 7,640 meters, but the pendant did not detach, whereas the freezing of water would have been met at a much lower altitude, in the vicinity of about 5 kilometers according to a graph on page 301, of this Review 55:301, Figure 5.

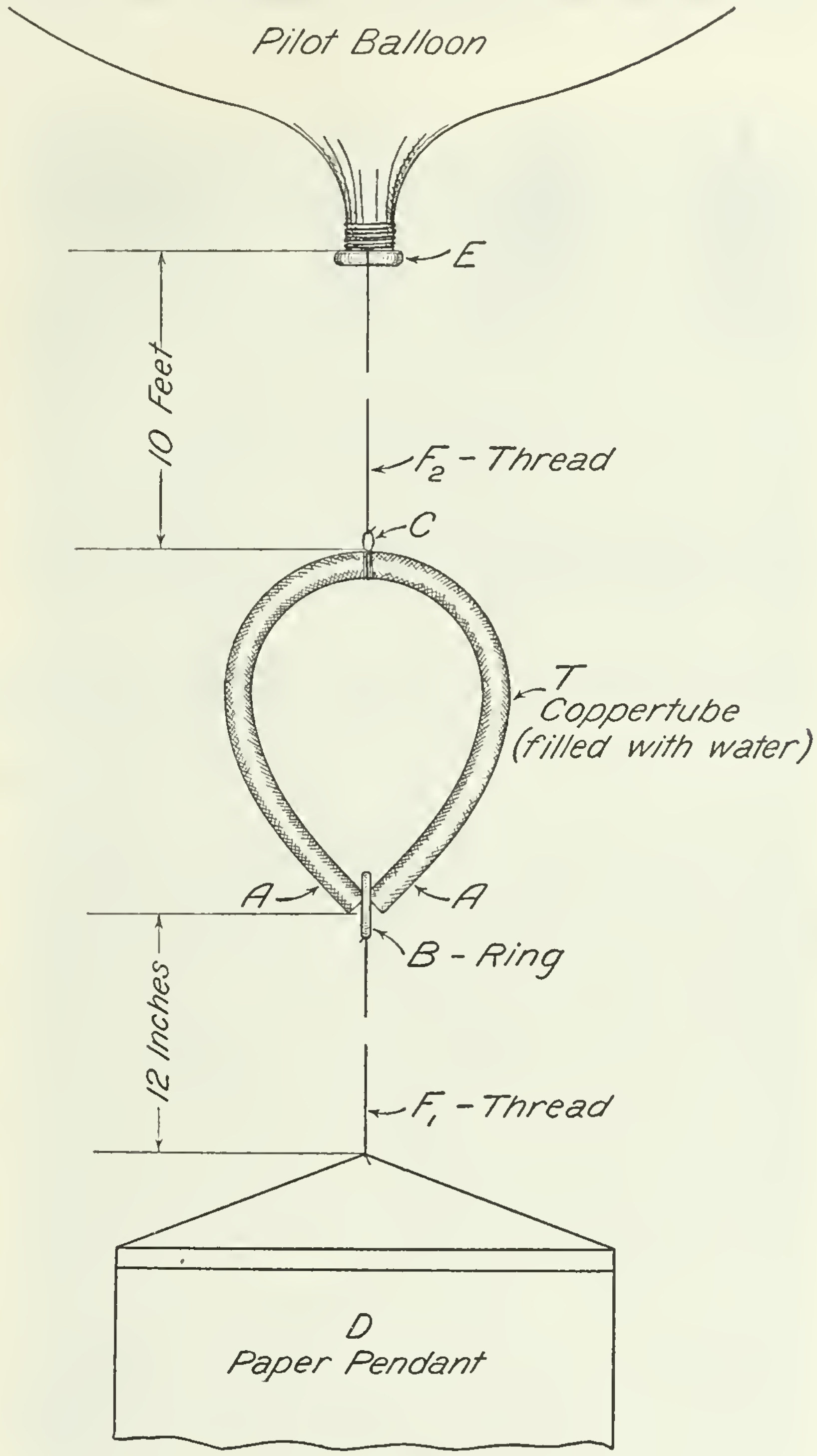

Figure 1

In a further letter dated March 30, 1931, Mr. Brennan gives an account of placing his device in a freezing mixture in which the arms of the tube separated at 23.5° F. A second test gave a similar result. He further estimates that the pendant should release in the latitude of Jamaica at about 6 kilometers altitude.

SOUNDING-BALLOON RELEASING DEVICE

By L. T. SAMUELS

A very satisfactory device has been designed by Mr. Berlin Pugh, of the Royal Center aerological station, which permits the balloon, after bursting, to detach itself from the parachute and meteorograph. This results in a much more satisfactory rate of descent of the instrument and consequently a more accurate record.

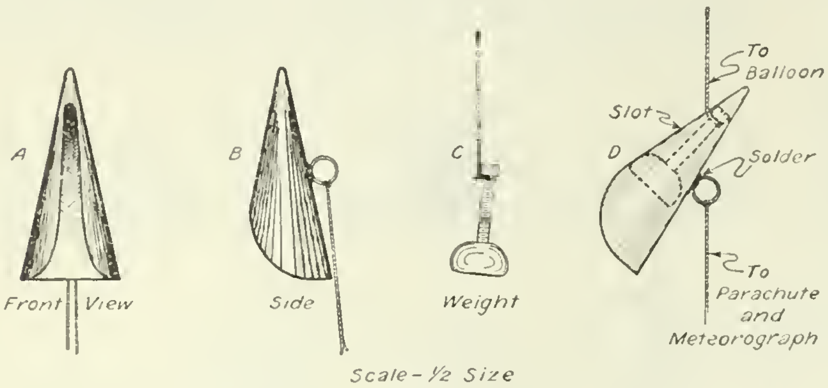

FIGURE 1.—Device for releasing parachute and meteorograph from sounding balloon after latter bursts

This device is shown in Figure 1 and consists of two parts, one, an aluminum slotted cone and the other, a brass weight. In Figure 1 *d* is shown how the two parts are used in an observation. One end of a cord is tied to the brass weight and the other end to the balloon. The brass weight is held inside the cone by the upward pull of the balloon. When the latter bursts, the brass weight slips out of the cone and the parachute is then free to operate during the descent of the instrument. A small wad of paper is put into the pointed end of the cone to prevent the brass knob from sticking.

The parachute used by the Weather Bureau is simply a square yard of bright red China silk. Cords are fastened to each corner and to the center. The other end of the cord attached to the center of the parachute is fastened to the aluminum cone. A light wire hoop about 1 foot in diameter is tied to the four cords attached to the corners of the parachute and prevents them from tangling and assures the opening of the parachute.

These devices were used with excellent results during a sounding balloon series at Royal Center, Ind., during February, the international month for 1931.

PYRANOMETER RECORDS ASSIST IN DISTINGUISHING BETWEEN HAZE AND CLOUDS

By A. F. GORTON, Associate in Meteorology, and S. W. CHAMBERS, Associate in Physical Oceanography

[Scripps Institution of Oceanography, La Jolla, Calif.]

The thermoelectric pyranometer[1] has a decided advantage over the standard Friez Weather Bureau sunshine recorder in that the record is strictly numerical or quantitative. The extreme range of the Engelhard recorder in use at the Scripps Institution of Oceanography, La Jolla, Calif., is 0–30 microamperes.[2] The maximum value for clear skies is a little over 20 microamperes (66.7 scale divisions) attained in June. Momentary readings as high as 25 microamperes (82.5 scale divisions) have been observed, due to radiation reflected from broken clouds. During the winter season lower values are reached, the record running between 12.5 and 13 (about 42 scale divisions) in the middle of the day, with clear skies.

The Kimball-Hobbs pyranometer at La Jolla has been functioning continuously for over two years, and a summary of the data has been published in the MONTHLY WEATHER REVIEW each month. In reviewing the accumulation of daily charts, the writers have been impressed by the fact that they apparently enable one to distinguish between days marked by *haze* and those marked by *scattered* or *continuous clouds* of considerable density, including "high fog."

Accompanying this note are sample charts which illustrate quite clearly the point in question; i. e., that the instrument easily distinguishes between what we may term "vapor," filmy cloud such as light cirrus, and clouds of material density. To be specific, that portion of the record of an apparently flawless day which is marked by a solid but jiggly line is due to what we have here called "vapor." This vapor or haze is often absolutely invisible to the eye. On the other hand, when scattered clouds of more or less density are present, the record jumps very erratically, changing as much as 4 to 8 microamperes in a few minutes' time. Furthermore, on days marked by dense cloud and rain, it is noticed that the line traced by the instrument is rather continuous but lies close to zero—in fact, the intensity may be six, four, or even less, scale divisions,[3] as is well shown by the records for May 5 and 16, reproduced in Figures 1–A and 2, respectively.

As previously stated, the instrument responds to scattered clouds by fluctuating between wide limits (figs. 1–B and 3), and on very bright, clear days makes a trace which is quite solid, i. e., *continuous*, but varies as much as 5 or 6 per cent during time intervals as short as 10 to 20 minutes. As illustrations of this point we cite the records for the afternoon of May 5 and 22, Figures 1–C and 4, respectively.

Finally, we have noticed another peculiarity of the instrument; that is, a tendency when scattered clouds are present for the record to exceed by as much as 2 to 3 microamperes the very maximum for a normal clear day. (See records for May 5 and 28, reproduced in Figures 1–B and 3, respectively.)

It is recognized, of course, that various types of haze, fog, and cloud exist, and here on the Pacific coast it is often difficult to distinguish precisely between them. We have observed, however, that variations of as much as 5 microamperes may be caused by what most people term "high

[1] Kimball, Herbert H. and Hobbs, Hermann E.: A new form of thermoelectric recording pyrheliometer. Monthly Weather Review, May, 1923, vol. 51, p. 239.

[2] It would be preferable to state the output of the thermocouple system in millivolts, but the latter may be calculated from the relation: E. M. F. in microvolts=412×current in microamperes. To reduce microamperes to gram-calories per minute per square centimeter, multiply by 0.055. Thus, 30 microamperes equals 1.65 gr.-cal./min./cm², and 20 microamperes equals 1.10 gr.-cal./min./cm². Also, scale readings on the record sheet may be reduced to gr.-cal./min./cm² by multiplying by 0.0165. A recent test by the Scripps Institution shows that the register has not changed in the three years it has been in service.

[3] Kimball, Herbert H.: Records of Total Solar Radiation Intensity and Their Relation to Daylight Intensity. MONTHLY WEATHER REVIEW, October, 1924, vol. 52, p. 473, fig. 5.

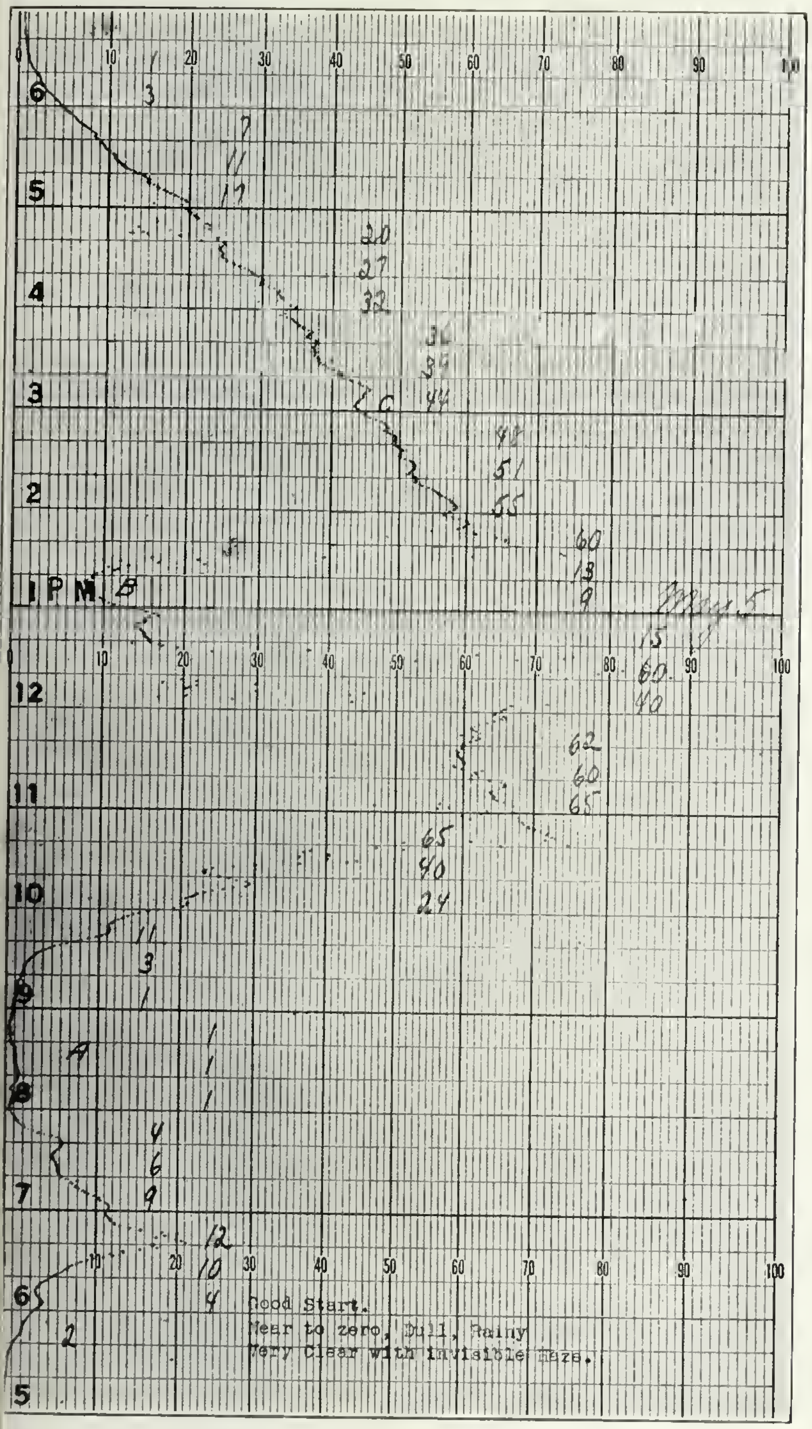

FIGURE 1.—Record for May 5, 1930. A, Dense cloud and rain; B, scattered clouds; C, invisible haze

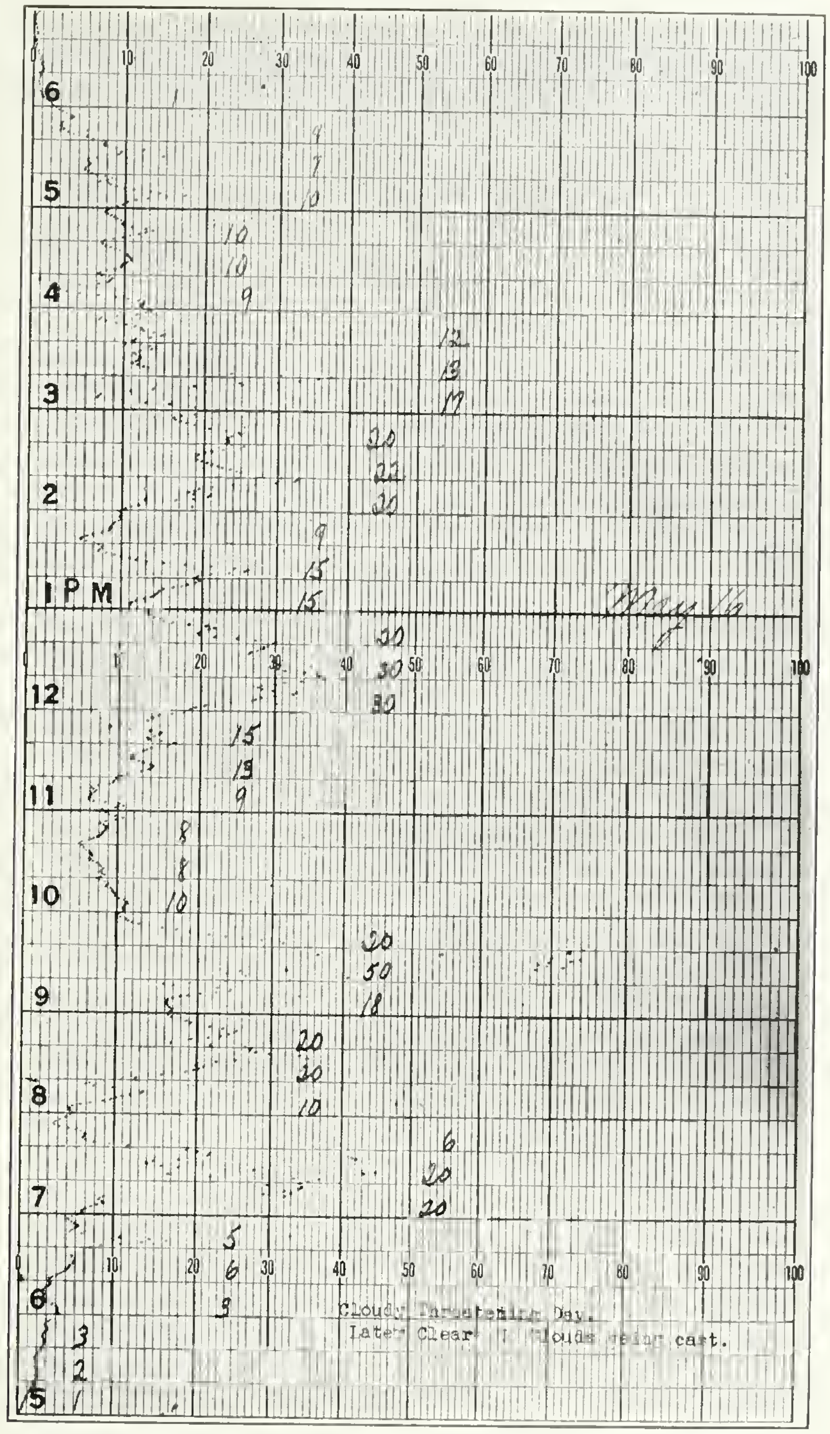

FIGURE 2.—Record for May 16, 1930. Cloudy day, with no shadows cast

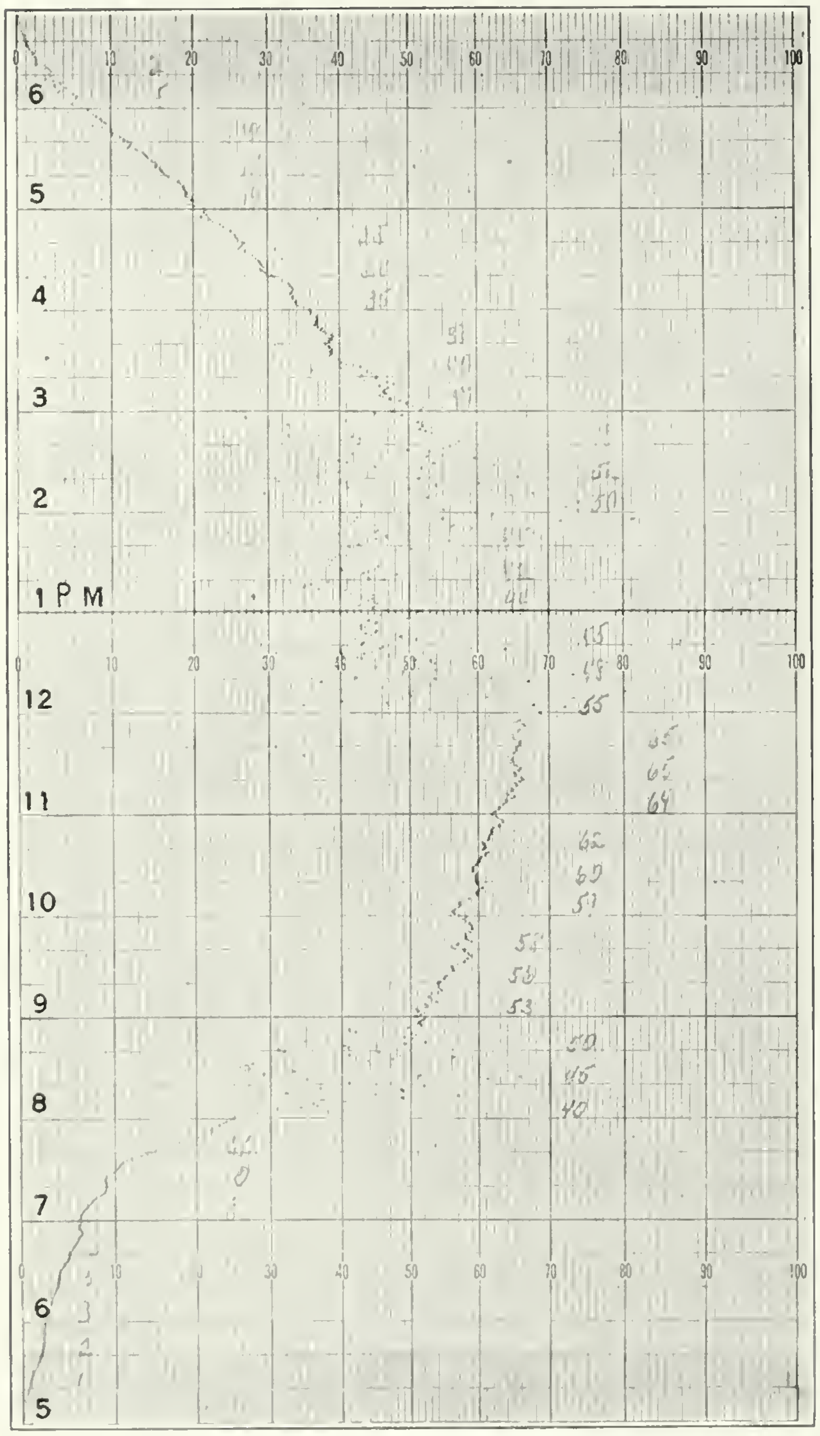

FIGURE 3.—Record for May 28, 1930. High fog

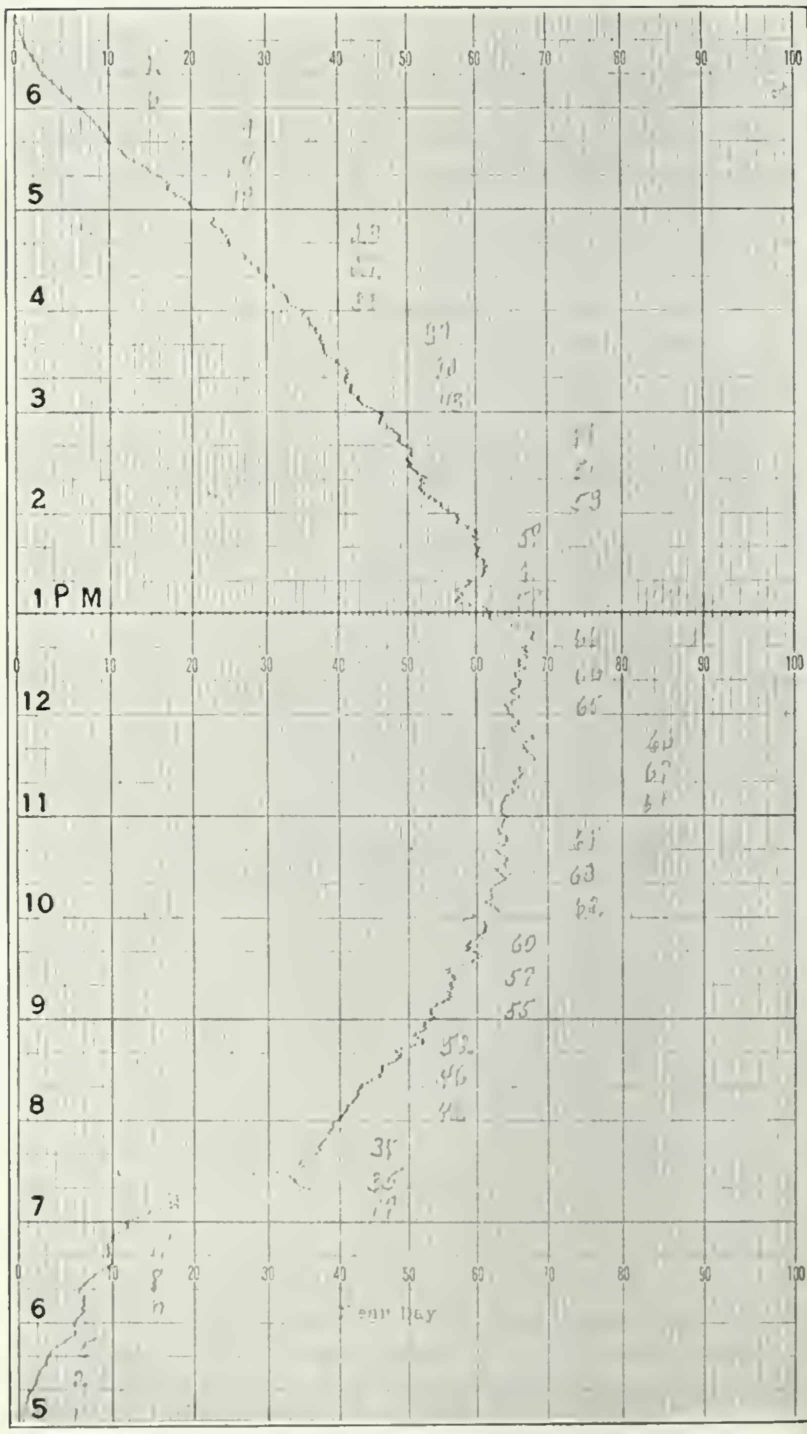

FIGURE 4.—Record for May 22, 1930. Invisible haze

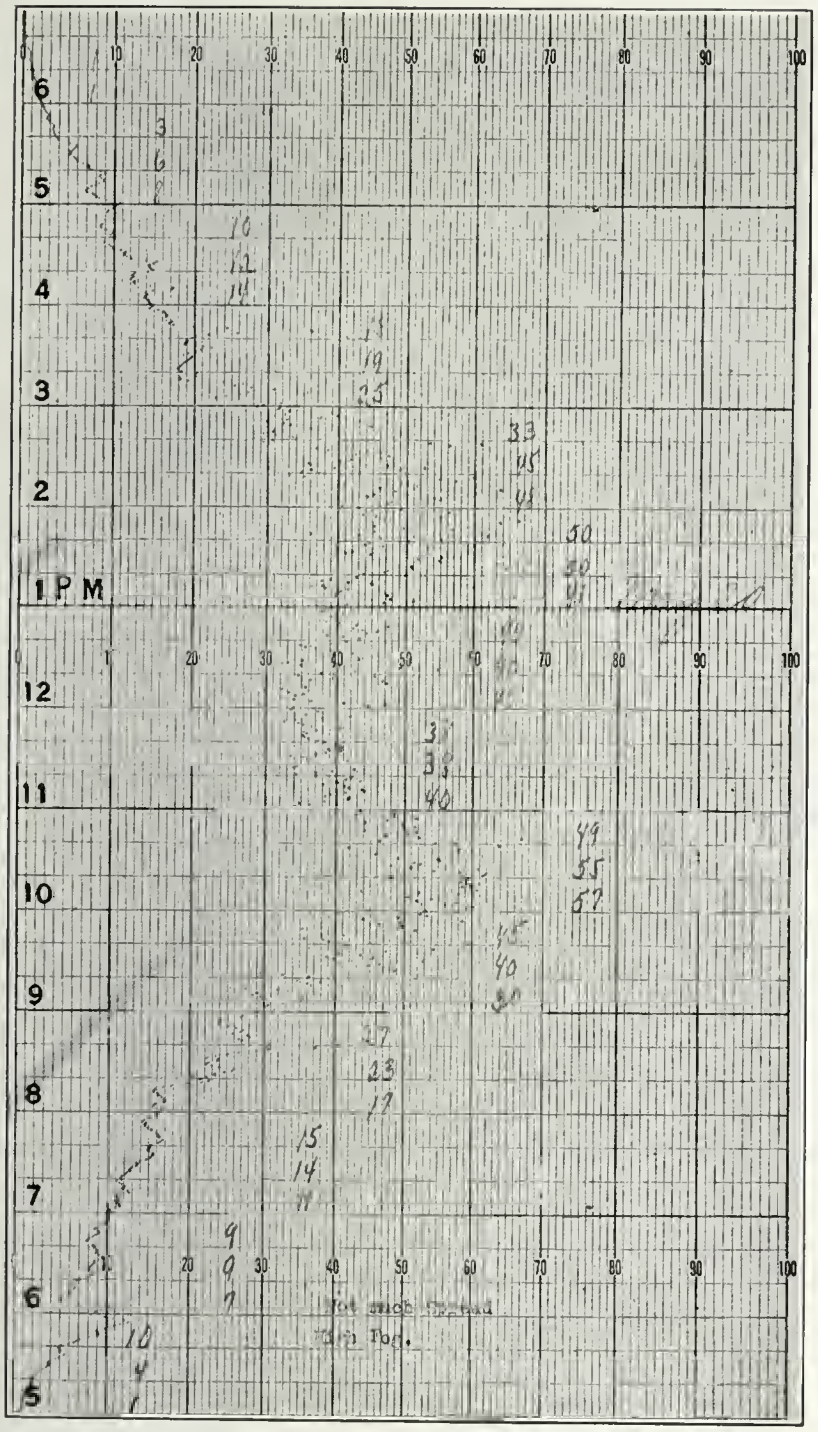

FIGURE 5.—Record for May 20, 1930. High fog

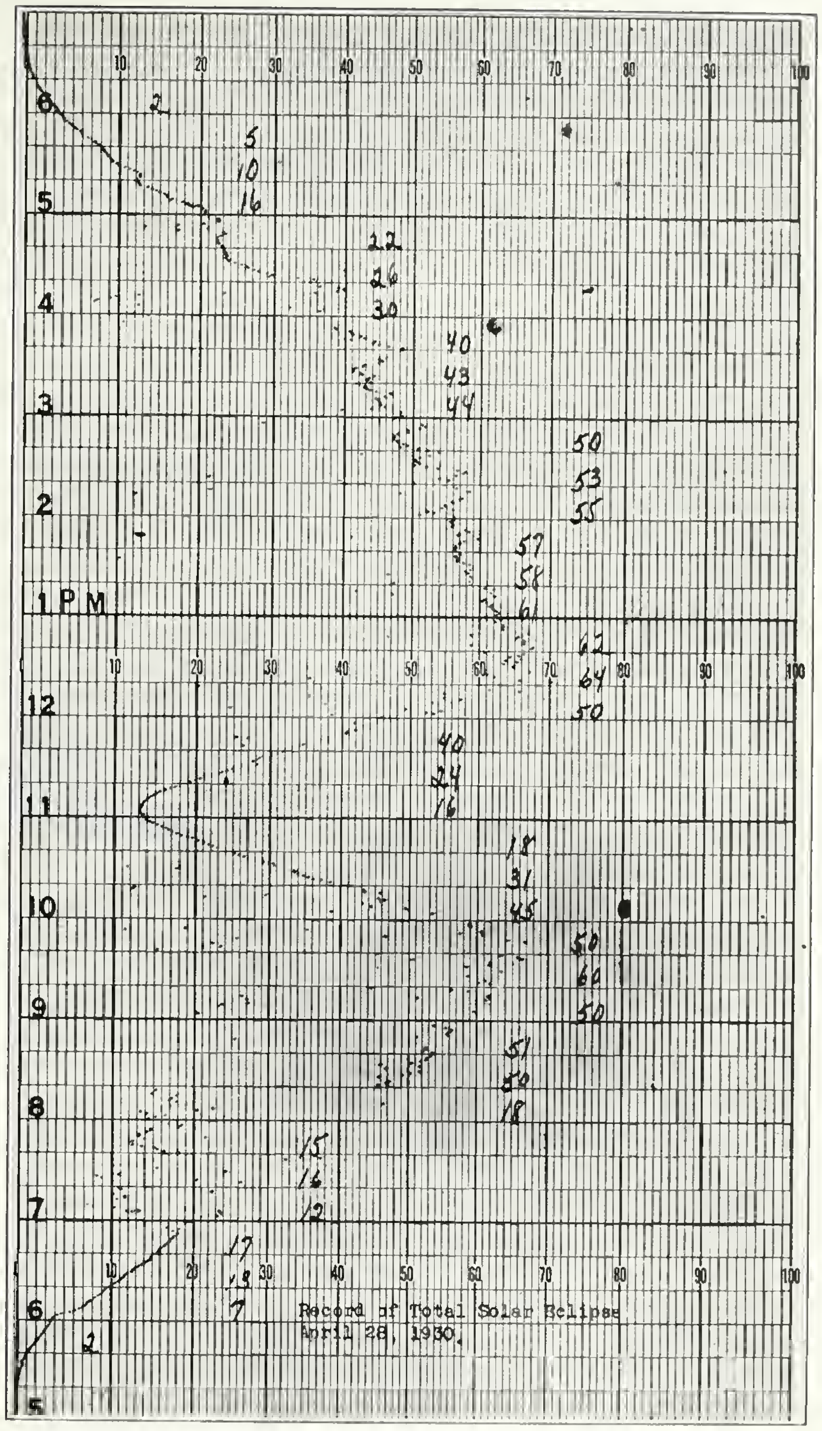

FIGURE 6.—Solar eclipse of April 28, 1930

fog." This term should be applied to cloud banks of considerable continuity and density,[4] and not confused with cirrus (high altitude) clouds or with ordinary "low fog."

Possibly we may establish a safer criterion by determining whether a shadow is being cast. We have observed that in some cases the record varies over 5 microamperes, but the total intensity is not much reduced below the maximum for a clear day. In these cases it was noticed that shadows were cast. On the other hand, when the cloud density increases sufficiently a shadow is no longer cast and the record sinks to 6 microamperes or less. As an illustration of some of these points we may cite the record for the day of the total solar eclipse, April 28, 1930. (See fig. 7.) Here it will be noticed that the trace becomes quite continuous below 12 microamperes (40 on the chart) having the smoothness of a record for a clear day but forming a beautiful V-shaped indentation in the record.

Kimball,[3] in several articles dealing with the design, construction, and performance of the pyranometer, refers to irregularities in the traces of the instrument on apparently clear days but comes to no definite decision regarding the probable cause of the irregularities. On another occasion he states that they may be caused by smoke. At a location like La Jolla, this hypothesis is ruled out, since the atmosphere is always smoke-free except on rare occasions when there are forest fires.

[4] See Carpenter, Ford A.: The Climate and Weather of San Diego. 1913, pp. 5–7.

[3] Kimball, Herbert H.: Records of Total Solar Radiation Intensity and Their Relation to Daylight Intensity. Monthly Weather Review, October, 1924, vol. 52, p. 473, fig. 5.

SOME CHARACTERISTICS OF CONTINUOUS RECORDS OF THE TOTAL SOLAR RADIATION (DIRECT+DIFFUSE) RECEIVED ON A HORIZONTAL SURFACE

By Herbert H. Kimball

In the paper preceding this, Gorton and Chambers have pointed out some interesting relations between the character of solar radiation records and the condition of the sky. Ångström [1] has already noted some of these relations at Stockholm, and especially the increased intensity with the sun shining between broken clouds.

In an earlier paper entitled "On Continuous Radiation Records and Their Bearing upon Geophysical Problems." (Särtryck ur Förhandlingar 17: de skandinaviska naturforskaremötet i Götehorg, 1923) he discusses the cloud formation during the passage of a cold-wave front at Stockholm on August 4, 1922. The formation of a uniform cloud layer preceded the arrival of the cold air at the surface by an appreciable time interval, and breaks occur in this cloud layer at uniform intervals of two hours. This is explained as follows:

> The upper boundary of the cold wave is in general subjected to a pronounced wave formation. Sometimes waves of higher orders are well developed. As a rule the uniform cloud layer appears at the wave tops, the breaches in the cloud layer at the valleys, but exceptions therefrom sometimes occur. In the special case referred to above the breaches in the cloud layer have occurred almost exactly at the lowest points of the waves.

Apparently, atmospheric waves sometimes occur without forming visible clouds. For example, in the Monthly Weather Review for September, 1915, volume 43, page 441, in Figure 1 are plotted logarithms of solar radiation intensity against air mass, measured on unusually clear days. With a sky of uniform clearness throughout, the plotted values should fall on a line only slightly concave upwards. Actually, however, the values fall on a wavy line, and especially those for Washington, during the afternoon of February 28, 1915, and for Mount Weather, Va., during the morning of September 28, 1914.

Attention has also been called to the effect of smoke on the solar radiation intensity. See, for example, Monthly Weather Review, volume 52, page 478, Figure 5, October, 1924, and volume 53, page 147, Figure 1, April, 1925. The first of these reproduces records of intensity of the total solar radiation received on a horizontal surface at the university station, Chicago, Ill., and its depletion by smoke on both a cloudless and a cloudy day. The second shows the depletion of direct solar radiation intensity at normal incidence at the American University, District of Columbia, by a smoke cloud that was brought over the university from the city by an east wind. Clouds of less density frequently cause depressions in the records obtained in the vicinity of any city.

It is apparent that much valuable information about sky conditions may be obtained from continuous records of the intensity of solar radiation as received on either a horizontal surface or on a surface normal to the incident rays.

[1] Ångström, Anders. Recording solar radiation. Medd. Från Statens Meteorologisk-Hydrografiska Anstalt, Band 4, No. 3, 1928.

COMPARISON OF ROOF AND GROUND EXPOSURE OF THERMOMETERS

By Bernard R. Laskowski

[Weather Bureau, Topeka, Kans.]

It is generally conceded that the average temperature eadings obtained from properly exposed thermometers 1 the Plains States, where the ground surface is level or lightly rolling, agree quite closely within a radius of rom 15 to 25 miles. What, however, is the relation etween official temperatures taken in downtown sections f middle-western cities and their suburbs? In other ords, do official temperatures taken on high buildings f cities reflect conditions under which people live in the esidence sections? It must be remembered that in a reat percentage of the larger cities the usual practice is o locate the thermometers on roofs of high buildings, while in the suburbs, the thermometers are more likely to be exposed over a ground surface. In order to investigate this question a 6-year record of daily maximum and minimum temperature readings was obtained in Topeka, Kans.

The thermometers used in this study were of standard pattern, compared for accuracy, and exposed in standard shelters having louvered sides and double-decked roofs. These favor the free circulation of the passing air, but do not absorb any added heat due to radiation or reflection from near-by objects or from the direct rays of the sun. One set, that of the Weather Bureau office, was

located 10 feet above the flat roof of a 6-story building, making an actual elevation of thermometers 92 feet above street level, in the center of the business district, and the other 5½ feet above the ground at a point a mile and a half away in the residential section. The size of the ground shelter is 21 by 32 inches; it has not a broad platform underneath it. The ground surface at both places is approximately the same elevation above sea level.

During the period of comparative readings some of the lowest readings ever recorded in the vicinity, as well as the highest on record in 44 years, occurred. This should eliminate the objection that just average conditions had prevailed during the experiment and extreme conditions might have altered the results obtained.

In most instances the individual monthly averages obtained from the ground surface readings were higher. Occasionally, though, during no definite seasons, the opposite was true. The wind movement and presence of snow and ice on the ground seem to have been the most apparent factors in making the differences so far as the study indicates. Taking the monthly averages for the six years into discussion, it is found that these averages compensate the individual monthly inconsistencies and the ground exposed readings exceed the roof readings each month, and for the entire period average by 0.6°. This fact in itself eliminates any need for correction for altitude, as the ground instruments are less than 100 feet below those on the roof. In case there was a noticeable altitude effect, it would tend to lessen the differences instead of increasing them.

The monthly mean maximum and minimum temperatures and extremes add more to the study than do the average readings. The ground-exposed maximum thermometer averaged 1.9° higher than the roof thermometer, while the minimum readings averaged 0.6° less. This may be accounted for by stating that the radiation effect at the ground should be greater than on the roof, where air passage is less hampered. This conclusion is indicated by the tables giving the monthly extremes and the extremes for the entire period. Whereas the monthly averages do much towards eliminating the observed discrepancies, the daily extremes exhibit examples of the various individual factors that tend to separate or draw together the readings.

For an example of wind effect, let us refer to several dates selected at random. On April 24, 1926, the wind, as recorded at the Topeka Weather Bureau office, averaged 19.9 miles per hour for the day, which is above the daily average wind movement. The high wind kept the air mass in continual turmoil, the result being a minimum temperature at the ground of 45° and on the roof 46°.

On June 9, 1927, the daily wind averaged 16.7 miles per hour and the minimum readings at both places were the same, 66°. On September 11, 1928, the wind averaged 13.0 miles per hour and the minimum on the ground was 64° while on the roof it was 63°. On December 2, 1929, the wind averaged 10.3 miles per hour, and again both thermometers registered the same, 10°.

Radiation effect is greater if the wind movement is light, permitting the air mass to become stagnant. The dates selected to illustrate this part of the wind factor are as follows: On April 26, 1926, with an average wind movement of 5.6 miles per hour, the minimum on the ground read 37° and the roof thermometer 42° On July 2, 1927, the wind averaged 5.5 miles per hour and the ground minimum was 57° while the roof minimum was 64°. On September 15, 1928, with an average wind movement of 3.3 miles per hour, the ground thermometer registered 54° and the roof thermometer 61°. On November 1, 1928, the wind averaged 4.9 miles per hour and the minimum on the ground was 29° while on the roof it was 34°. All the days considered in these cases were either clear or mostly so. It will be observed that the days selected represent each quarter of the year which indicates that this factor is not limited to any particular season.

For cases to demonstrate what effect a snow blanket has on the ground temperature we refer to the period of January 12 to 16, 1927. Snow several inches in depth occurred on the 12th and 13th, leaving 4 inches on the ground at the close of the 13th. The next morning with a clear sky and wind averaging 10.2 miles per hour, the ground thermometer registered 5° while the roof thermometer registered 8°. Practically the same sky and wind conditions prevailed through the 16th. On the 15th the ground thermometer read 14° below zero and the roof thermometer 9° below zero. On the 16th the ground minimum was 16° and roof reading 23°. The period of January 22 to 25, 1930, also illustrates this point. Previous to the 22d, snow had fallen and the ground was covered to a depth of 9.0 inches. The sky was clear from the night of the 21st to the morning of the 25th. The average wind movement the 21st to 22d was about 5 miles an hour. The ground thermometer that morning read 19° below zero and the one on the roof read 13° below zero., which by the way, is the lowest recorded at the Weather Bureau in 11 years. The wind movement from the 23d to the 25th averaged between 9 and 10 miles per hour. On the morning of the 23d, the ground reading was 7° below zero while the roof reading was 1° above zero. On the 24th the low point at the ground was 9° compared to 12° on the roof. The morning of the 25th the ground thermometer indicated 3° and the one on the roof 11°.

The daily maximum readings did not show as great differences as the minimums, but this can be accounted for by the fact that the maximum generally occurs in the latter part of the afternoon when the wind movement is at its highest, resulting in the air mass at the ground at that time being about as active as on the roof. For this reason the maximum readings on the roof and ground agreed uniformly within one or two degrees, and any number of times were exactly the same. A case in this connection was August 3, 1930, when the Weather

Bureau thermometer registered 110°, which was the highest reading ever recorded in 44 years. The ground thermometer corresponded exactly. The sky was mostly clear and the wind averaged 11.9 miles per hour.

The slightly higher day readings and lower night readings signified that the daily range must be proportionately greater at the ground. This varied from time to time. For the entire period the monthly mean daily ranges differed by 2.4°. The daily range varied from day to day, sometimes being close together and then again at wide variance. The greatest differences occurred during quiet spells when the radiation effect was greatest.

Actual practice in the United States Weather Bureau is to employ ground exposure at some 4,500 cooperative stations and at as many first-order stations as possible. Roof exposures are accepted only through necessity, never from choice.

The results of the comparative readings are summarized on a monthly basis in the table below.

TABLE 1.—*Summary of comparative readings, monthly means, and extremes*

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mouthly means, ground.	26.9	37.6	46.3	57.1	64.9	73.0	79.6	77.6	70.5	57.8	43.2	31.8	55.5
Monthly means, roof	26.6	37.0	45.0	56.0	64.4	72.2	79.0	77.3	69.8	57.9	42.6	30.8	54.9
Monthly means, maximum ground	36.9	48.7	58.9	68.8	76.5	83.9	91.2	89.2	81.8	69.4	54.0	42.0	66.8
Monthly means, maximum roof	35.6	46.7	56.1	66.1	74.8	82.0	89.3	88.0	80.0	68.4	52.3	39.9	64.9
Monthly means, minimum ground	16.9	26.5	33.7	45.5	53.3	62.1	68.0	65.7	59.2	46.1	32.3	21.6	44.2
Monthly means, minimum roof	17.6	27.4	34.0	45.9	53.9	62.4	68.7	66.6	59.6	47.4	32.9	21.7	44.8
Absolute maximum, ground	66	83	89	93	95	99	105	110	102	93	83	68	110
Absolute maximum, roof	68	83	88	93	96	100	104	110	101	93	84	68	110
Absolute minimum, groud	−19	−11	0	14	34	46	51	49	35	16	5	−9	−19
Absolute minimum, roof	−13	−7	4	17	35	49	52	52	38	16	10	−9	−13

FURTHER NOTES ON THE EFFECT OF WEATHER ON APPLE YIELDS

By W. A. MATTICE

[Weather Bureau, Washington, D. C.]

The effect of temperatures on apple yields was studied during 1927 by the author and the results published in the Monthly Weather Review.[1] The effect of precipitation, however, was not considered at that time as the purpose of the study was to substantiate the theory that spring temperatures were largely a determining factor in apple production. The precipitation by months was studied rather casually in a preliminary survey, but no definite relationship was established. However, a bulletin of the New York Agricultural Experiment Station by R. C. Collison and J. D. Harlan[2] was forwarded by the senior author for information as regards its conclusions. This publication contains the results of a rather exhaustive survey of an orchard of 50 Rome Beauty apple trees in New York. The conclusions drawn are that temperature departures from normal are not an important factor influencing yield, but that precipitation departures from normal are very important, especially those for the period from July 16 to September 1. It is also shown that the most critical period of these six weeks is that between July 31 and August 15. These conclusions, if they could be correctly applied to the entire State, would depreciate the spring temperature theory. In order to check these conclusions with State yields it was decided to collect rainfall data from the temperature stations and find such relationships as might exist.

The daily precipitation for three months, June to August, inclusive, was obtained and weekly amounts computed. Thus, the weekly periods covered the time from June 1 to August 30 and should show the critical period by the magnitude of the correlation coefficients.

The individual correlation coefficients for these 13 weeks are given below:

Week ending—	Correlatiou coefficient	Week ending—	Correlation coefficient
June 7	−0.14	July 26	0.07
June 14	.23	Aug. 2	−.06
June 21	.21	Aug. 9	−.05
June 28	−.18	Aug. 16	−.22
July 5	.36	Aug. 23	.20
July 12	−.29	Aug. 30	.14
July 19	.06		

The magnitude of the coefficients is very small, the largest being only 0.36, which is hardly large enough to consider. There is some significance, however, in the largest coefficients occurring in pairs, as it would appear from this 2-week periods are of more importance than single weeks. The coefficients of these 2-week periods with yield, by multiple correlation methods, were: June 7–21, 0.26; June 29–July 12, 0.59; August 9–23, 0.29. The increase of the coefficient for the weeks June 29–July 12, from 0.36 to 0.59, is rather striking. This is due to the fact that, while the two weeks have a positive and negative relationship with yields, the correlation between them is positive; thus the relation of both with yield is very much better in combination than separate.

The three 2-week periods were combined in a multiple correlation, giving a coefficient of 0.64, or only 5 points better than the coefficient of the weeks June 29–July 12. These six variables then were put into an equation in order to compute yields from them. The equation follows:

$$\overline{X} = 1.14\ A - 0.31\ B + 3.16\ C - 5.30\ D + 0.95\ E + 2.34\ F + 8.22$$

The letters A, B, C, etc., refer to the single weeks, June 14, June 21, July 5, etc.

The computed yields from this equation gave a reduction of the standard deviation of 23 per cent. The reduc-

[1] Mattice, W. A. (1927): The Relation of Spring Temperatures to Apple Yields. MONTHLY WEATHER REVIEW, 55, 10: 456–459.

[2] Collison, R. C., and Harlan, J. D. (1927): Annual Variation in Apple Yields—A Possible Cause. Technical Bulletin No. 126, New York Agricultural Experiment Station, Geneva, April, 1927.

tion is rather small, but is valuable for forecasting purposes, as it enables one to come closer to actual yield than is possible using the average yield.

The use of these computed yields as a base for combination with the yields computed from the temperature data is following the method outlined by J. B. Kincer.[3] The yields computed from the rainfall data are called Yr and those from temperature Yt. Thus, the correlation coefficient, $rYtYrx=0.87$. This is an increase of 6 points over that obtained only from temperatures and gives a reduction of the standard deviation of 51 per cent, an increase of 10 per cent over that from temperatures alone.

It is not well to stop here, however, as some other combination of weeks might raise the coefficient. A small increase at these high values is very important, so it is worth while to try other combinations.

Thus, dropping the first week used, June 14, and combining the remaining weeks, gives a coefficient of 0.63, one point less than for the whole six weeks. It would appear that these weeks would not give such a high coefficient as the entire six, but the intercorrelation coefficient is only 0.39, against 0.46 for the whole period. The multiple coefficient is 0.88 against 0.87, or an increase of one point, a valuable increase, as there is a 2 per cent further reduction in standard deviation, bringing it to 53 per cent. The equation for computing yields from these latter variables was:

$$\overline{X}=0.58\ Yr+0.80\ Yt-3.93$$

Figure 1, shows the computed and actual yields for 1901–1925. The agreement is remarkably close, considering the range of the data, although a few years are still somewhat at variance with the actual yields.

[3] Kincer, J. B., and Mattice, W. A. (1928): Statistical Correlations of Weather Influence on Crop Yields. MONTHLY WEATHER REVIEW, 56, 2.

The standard deviation of computed from actual yields is 1.92, compared with the standard deviation of yield, 4.05; the reduction is 53 per cent, as before stated.

The period of two weeks ending with July 12 was also correlated with temperature and yield and produced a coefficient of 0.85, or only three points less than with the five periods and two less than with all six weeks. This, in itself indicates that the period from June 29–July 12 is a critical one for precipitation, although the other periods are of some slight importance.

Some other combinations were tried in order to exhaust all possibilities, but there was none that gave as satisfactory a result as that for five weeks.

The conclusions that can be drawn from the above statements are that temperatures are of major importance in the yield of apples, on a State basis, and that precipitation is only of secondary importance. These conclusions are possible only to State yields and can not be applied to single orchards, as demonstrated in the conclusions obtained by R. C. Collison.

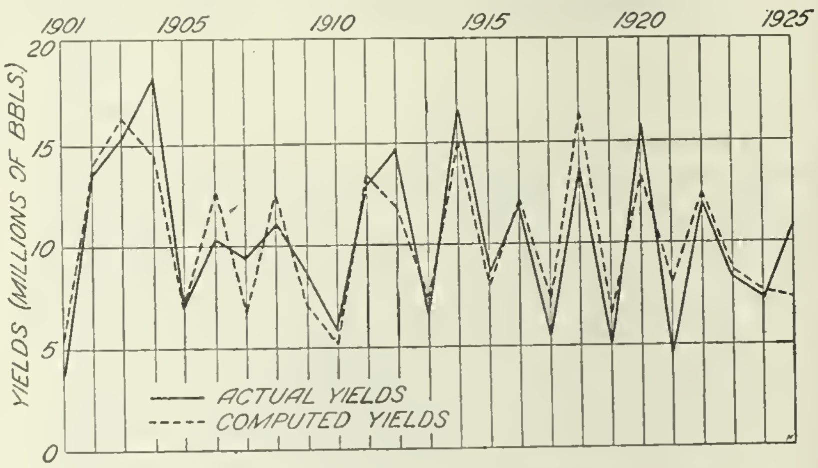

FIGURE. 1—Actual and computed yields of apples, New York State

EFFECT OF OZONE ON THE TEMPERATURE OF THE UPPER AIR

By EDWARD H. GOWAN

Two papers have been recently published by this author.[1]

The following abstracts are reprinted from Science Abstracts 32; 430 (1929) and 34: 58 (1931).

The illustrations are from the original papers.

The paper deals with the radiative equilibrium of the upper part of the atmosphere, taking into account the effects, with selective absorption, of water vapor and ozone. For material the author used (1) Abbot's curve for the distribution of energy in the solar spectrum from 0.4μ to 1.2μ and a black-body curve for 6,200° K. for 1.2μ to 6μ; (2) average radiation as for a black body at 260° K. from the earth and a moisture-laden atmosphere below 11 kilometers; (3) the amount of O_3 as constant and equal to a thickness of 3 millimeters at N. T. P. with a center of gravity at 30 to 40 kilometers; (4) a smooth average curve for absorption of O_3; (5) Fowle's figures for the absorption of H_2O vapor; and (6) saturation at 11 kilometers for 219° K. for H_2O vapour. Curves show the results obtained for temperature and height for (1) absorption and radiation due to H_2O vapor alone; (2) the observed amount of O_3 distributed as for O_2 down to 40 kilometers; and (3) an assumption of a change in distribution of O_3 to keep the temperature at 300° K. up to 150 kilometers. The effects on the temperature of (1) a different H_2O vapor distribution; (2) variation of absorption with temperature and pressure; and (3) a change in the center of gravity of the O_3 are discussed. The final temperature distribution arrived at agrees well with sound ranging and meteor observations.—*R. S. R.*

58. Effect of Ozone on the Temperature of the Upper Atmosphere, Part II, E. H. Gowan. Roy. Soc., Proc. 128, pp. 531–550, August 5, 1930. The method described in an earlier paper (see Abstract 430 (1929) is rendered more easy of solution by certain assumptions and allowance is made for diffusion of radiation from the earth. Preliminary estimates of the rate of cooling of the upper layers of the stratosphere and consideration of independent observational evidence of meteors lead to the belief that mixing of the constituents is general far above the tropopause. The radiation from the stratosphere must then be less and since the absorption of solar energy is the same, higher temperatures result. The maximum temperature attainable is investigated, this being governed by the rate of thermal decomposition of ozone and the rate at which ozone is formed in the atmosphere. The assumption of radiative equilibrium is reexamined in relation to convection being sufficient to insure mixing and the idea is retained. The effect of water vapor distributions for (*a*) no convection and gases in gravitational equilibrium, and (*b*) enough convection to give a constant composition is illustrated by calculations for varying conditions. The effects of different distributions and amounts of ozone and different zenithal angles of the sun are similarly treated. It is concluded that plausible distributions of ozone and water vapor provide the basis for a quantitative explanation of sound wave and meteor phenomena.—*R. S. R.*

[1] Proc. Roy. Soc. London A 120:655 (1928) and A 128:531 (1930), the second paper being an extension of the first.

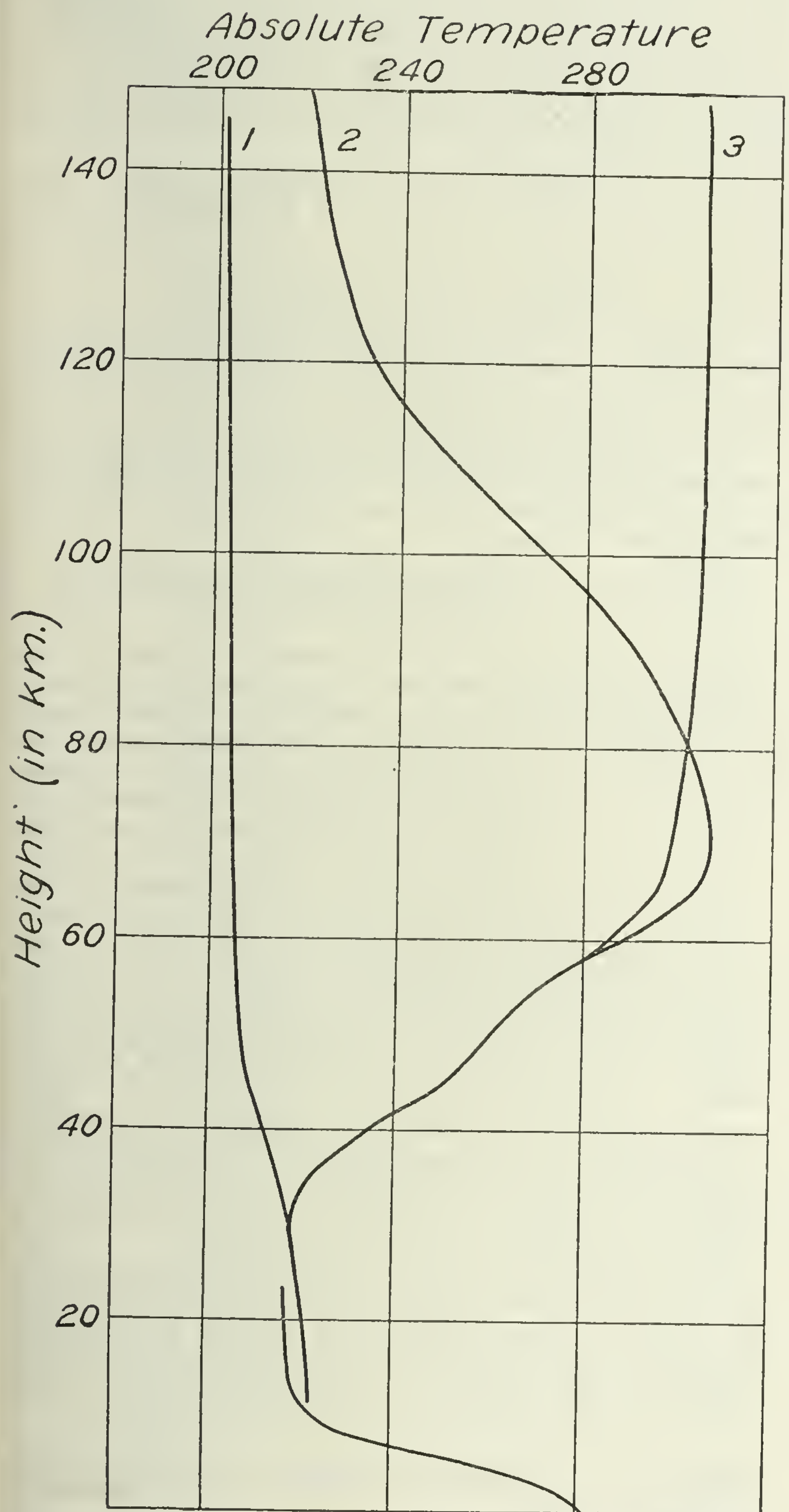

Figure 1.—Curve 1 shows an average of the balloon observations given by Sir Napier Shaw in Part II of his Manual of Meteorology. Curve 2 was obtained by considering the absorption and radiation of water vapor alone. The curve was intended for use as a basis of comparison. Curve 3 is the result when the observed amount of ozone is distributed so as to be proportional to the oxygen down to 40 kilometers. From 30 to 40 there is the same amount as in the layer from 50 to 60, and below that no appreciable amount is assumed

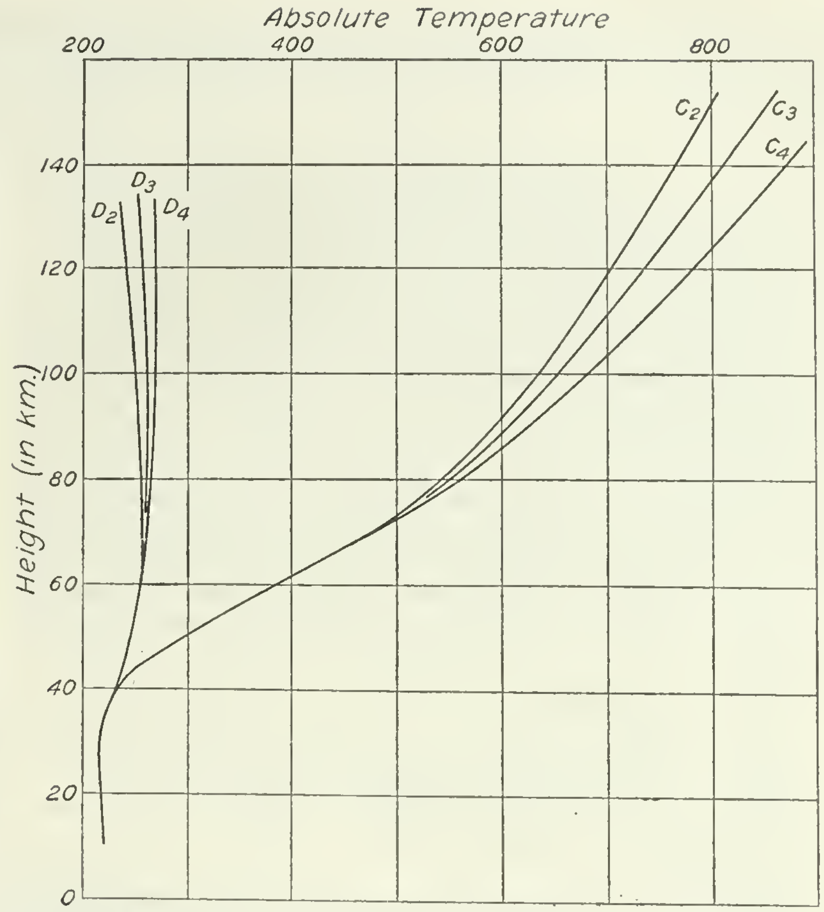

Figure 2.—Effect of variations in amount of ozone, distribution B. D-family: Water vapor distribution A. C-family: Water-vapor distribution B. Subscripts 2, 3, 4 represent total amount of ozone, millimeters

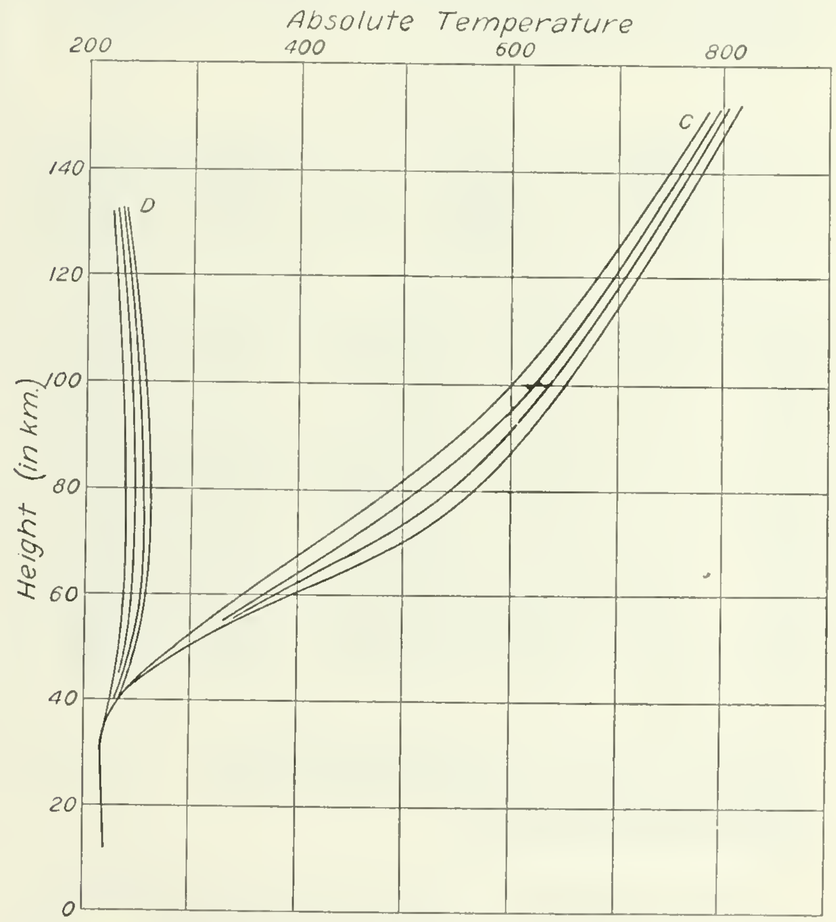

Figure 3.—Effect of zenith angle of the sun. Ozone distribution B for 2 millimeters total. D-family: water vapor distribution A. C-family: Water-vapor distribution B. From right to left the curves are for zenith angles of 0°, 28°, 48°, and 60°.

PREDICTION OF SEASONAL PRECIPITATION IN CALIFORNIA

By JAMES M. JONES

[Weather Bureau, Eureka, Calif., November 15, 1930]

That the winters in California are relatively wet and the summers dry is too well known to require comment.

The winter rains and snows in the mountains store up the water so vitally necessary for irrigation and power purposes during the long dry summers. Hence it is obvious that any successful method of predicting seasonal or semiseasonal rainfall in this region would be of incalculable value, and many able meteorologists are at work on the problem.

But what is the nature of this seasonal precipitation in California? Does rain begin always at about the same date and continue until another fairly well established date? Is there a fixed date about the middle of the season on which we may say that half of the seasonal precipitation has now fallen and as much more may be expected? Let us investigate, taking the record at Eureka as our guide.

At all California stations the precipitation season is assumed to begin July 1 and to end June 30, so that January 1 is the mid-season date by the calendar.

But some seasons start wet and end dry, other seasons start dry and end wet, and some run close to the average throughout.

Table No. 1 shows, by seasons, the total precipitation at Eureka, one-half of the total, and the date on which the total since the preceding July 1 amounted to one-half of the total for the entire season. A study of this table reveals some interesting facts, viz:

TABLE 1

Season	Total precipitation for season	One-half total	Date on which one-half of total had been received	Season	Total precipitation for season	One-half total	Date on which one-half of total had been received
1887–88	34.47	17.23	Jan. 30	1909–10	40.36	20.18	Dec. 9
1888–89	34.14	17.07	Feb. 25	1910–11	32.09	16.04	Jan. 19
1889–90	74.10	37.05	Jan. 23	1911–12	38.70	19.35	Feb. 7
1890–91	35.41	17.70	Feb. 23	1912–13	36.03	18.01	Jan. 9
1891–92	38.14	19.07	Jan. 8	1913–14	37.32	18.66	Jan. 16
1892–93	49.17	24.58	Feb. 4	1914–15	42.42	21.21	Jan. 11
1893–94	55.20	27.60	Jan. 13	1915–16	39.99	20.06	Jan. 15
1894–95	45.97	22.98	Jan. 12	1916–17	31.36	15.68	Jan. 29
1895–96	52.45	26.22	Feb. 28	1917–18	24.34	12.17	Feb. 5
1896–97	51.10	25.55	Feb. 1	1918–19	39.80	19.90	Feb. 5
1897–98	35.12	17.56	Jan. 19	1919–20	23.95	11.98	Feb. 21
1898–99	35.72	17.86	Feb. 1	1920–21	48.81	24.40	Dec. 30
1899–1900	51.73	25.86	Dec. 30	1921–22	34.76	17.38	Feb. 9
1900–1901	47.58	23.79	Jan. 2	1922–23	25.18	12.59	Dec. 27
1901–02	51.96	25.98	Feb. 10	1923–24	29.72	10.36	Dec. 18
1902–03	51.73	25.86	Jan. 21	1924–25	41.50	20.75	Jan. 13
1903–04	65.21	32.60	Feb. 16	1925–26	26.78	13.39	Jan. 2
1904–05	32.74	16.37	Dec. 30	1926–27	50.58	25.29	Jan. 2
1905–06	38.50	17.90	Feb. 14	1927–28	30.71	15.36	Feb. 3
1906–07	50.54	25.27	Feb. 2	1928–29	29.49	14.70	Dec. 27
1907–08	35.99	18.00	Jan. 13	1929–30	23.53	11.77	Jan. 17
1908–09	42.96	21.48	Jan. 17				

Average date to which one-half of seasonal total has fallen, Jan. 21.
Earliest date with one-half of total seasonal recorded, Dec. 9, 1909.
Latest date with half of total recorded, Feb. 28, 1896.
Number of times earlier than Dec. 28, 4.
Number of times later than Feb. 14, 4.

1. The average date on which the halfway point in seasonal precipitation is reached is January 21.

2. One-half of the seasonal total has been recorded as early as December 9 (in 1909).

3. One-half of the seasonal total has occurred after February 28 (1896).

4. The season of 1895–96 was a wet one with a total precipitation of 52.45 inches, one-half of which fell after February 28.

The season of 1899–1900 was also a wet one with a total precipitation of 51.73 inches, but in this case one-half of the total amount was recorded before December 30.

5. In the dry season of 1919–20 (total 23.96 inches) one-half of the total amount fell after February 21. In the dry season of 1923–24 (total 20.72 inches) one-half of the total precipitation was recorded before December 18.

From the foregoing the conclusion is reached that more progress might be made if investigators would shorten the period for which they seek to make precipitation forecasts by means of ocean temperatures, etc. Accurate forecasts for even so short a period as two or three months would be of great value and it would seem that success in the making of such forecasts should be more easily attained than if the prediction attempts to cover an entire season, which, as we have seen, may be composed of a very wet part and a very dry part, such radically differing conditions certainly not resulting from the same cause and, therefore, not being predictable from the same data.

STORY TOLD BY THE TREE RINGS IS COMPLICATED BY THE DROUGHT [1]

The time-honored method of telling the ages of trees by the annual rings has been upset this year by the peculiarity of the season, says the Forest Service. Trees in most sections got off to a good start in the spring but were halted by the parching summer drought. Almost everywhere the growth of trees this year has been slight, but in some areas where late summer rains soaked the earth, a second period of growth followed the drought, and so altered the ring records. This has been the case in Alabama, according to reports from the State forester.

When a tree puts on a year's growth it adds a new ring of wood, and the diameter increases by double the thickness of the last tree rings. The age of a tree can therefore usually be told by counting the rings on the stump. As a consequence of the halting and the new advance in growth this season, Alabama trees in many cases put on a second thin layer, known to foresters as a "false ring." So the foresters of future years will have to be on their guard in computing ages in the living calendars of Alabama tree stumps. Such false rings are not uncommon over long periods of years.

This year's regular ring in most parts of the country shows much less thickness than the average year's ring, and even in those regions where growth was renewed late in the season the second ring has not resulted in a larger total year's growth. Most regions, however, did not get rain early enough to start the second ring.

REVISION OF WEATHER BUREAU PRECIPITATION NORMALS (MONTHLY WEATHER REVIEW SUPPLEMENT NO. 34)

The daily, monthly, and annual precipitation normals for the first-order stations of the United States Weather Bureau have been revised and the revised normals published in MONTHLY WEATHER REVIEW SUPPLEMENT No. 34, issued during the latter part of 1930.

The revision is based upon the 50-year period, January 1, 1878, to December 31, 1927. Ninety-six of the

[1] Reprinted from the Official Record, U. S. Department of Agriculture, Jan. 1, 1931.

present first-order stations had complete records for the entire period and the remaining 101 stations, many of which had records for 20, 30 and 40 years, were reduced to the basic period either by interpolating the monthly amounts for the missing years directly from charts of monthly totals of precipitation or by correcting the shorter periods to the full 50 years by the usual methods of comparison with the data from near-by stations. The total number of stations is 197.

The SUPPLEMENT also contains for each station the consecutive 14-day sums of the actual unsmoothed precipitation, from the beginning of January to the last fortnight of the year, which naturally contains 15 days.

An error is noted on page 30 (Erie, Pa.), viz, the annual total given as 39.36 inches should be 36.93 inches.—*A. J. H.*

RAINFALL OF 1930 IN ALASKA

Whereas extreme drought prevailed over large areas in continental United States during 1930, the Territory of Alaska seems to have had generous rains. Rainfall measurements in that Territory have not given, as yet, dependable averages except at individual stations. The rainfall on the average for Alaska during 1930, as computed from stations having a full year's record, may be placed at 34.42 inches; that amount is considerably more than the probable annual average for the Territory. A recent contribution to this REVIEW [2] places the mean annual precipitation of fully two-thirds of the Territory at less than 20 inches. It may be remembered that the precipitation of Alaska is heaviest along the southeast coast and lightest in the interior valleys; thus the mean for coastal Alaska at Juneau is 81.6 inches, and for Fairbanks, near the Yukon, but 11.7 inches. The departure from these means for 1930 was +15.8 inches for Juneau and +5.3 for Fairbanks.—*H. C. Hunter.*

THE INTERNATIONAL ICE PATROL SEASON OF 1930 [3]

The United States Coast Guard is gradually accumulating meteorological and oceanographic data for the region of the Grand Banks that must be of the greatest value to future students of navigation in that fog and ice infested region. The report for 1930 is already at hand and fully measures up to the standard set for previous years.

Icebergs in 1930 appeared off the Grand Banks of Newfoundland very much earlier than usual; accordingly, on February 11, the *Tampa* left Boston, Mass., in obedience to orders from United States Coast Guard headquarters, to make an ice-observation cruise. The *Tampa* reached the Tail of the Grand Banks 48 days earlier in the year than the first ice-patrol vessel did in 1929. The *Tampa* was relieved of the patrol duty by the *Mojave* on February 27, and the last-named in alternation with the *Modoc*, took on the patrol work for the remainder of the season.

[2] Fitton, Edith M.: The climates of Alaska, MONTHLY WEATHER REVIEW 58:85-103.
[3] U. S. Treasury—Coast Guard Bulletin No. 20, Washington, 1931, 50 pp., numerous charts and tables.

In May there were remarkably few bergs off the eastern edge of the Grand Banks. This failure of berg supply, as much as anything else, caused the extraordinarily ice-free conditions that were enjoyed south of the forty-sixth parallel throughout the remainder of the season. The season closed on June 10, unusually early.

Capt. Cecil M. Gabbett, commanding the Ice Patrol, commenting on the season remarks as follows:

> There was a marked deficiency of ice south of the Tail of the Grand Banks, as in 1927 and 1928. In 1930, only six different bergs drifted south of the forty-third parallel, the latitude of the Tail. This small number can be attributed partly to the unusually small amount of field ice reported this year from southeast of Newfoundland and partly to the narrowness of the southward-flowing cold stream off the eastern edge of the Grand Banks. Both of the above factors in turn doubtless depend upon the winds and the weather conditions that prevailed north of Newfoundland and Labrador during the preceding winter months. * * * After May 24 no bergs were sighted or reported, except north of the Grand Banks and along the Newfoundland coast in the vicinity of Cape Race and St. John's.
>
> Throughout the season, the usual extension of cold water to the westward around the Tail of the Banks was largely absent.—A. J. H.

Temperature and visibility data are given in the subjoined table.

Temperature (F.) and visibility during International Ice Patrol, 1930

	Feb.	Mar.	Apr.	May	June [1]
Maximum	44	59	55	67	[1] 70
Minimum	25	22	29	36	37
Mean	33.3	39.6	39.6	47.1	51.6
Visability less than 2 miles, per cent of time	3	26.4	25.8	30.5	40.6

[1] For June 1-12 only.

SIMPLIFIED FORMULAS FOR RAINFALL INTENSITY [4]

By C. E. GRUNSKY

Subsequent to the publication of the simplified formulas for rain intensity in the MONTHLY WEATHER REVIEW of October, 1930, the writer's attention was called to the fact that the information obtained from the observer at Dam No. 4, Nuuanu Valley, Honolulu, was incorrect. The total rain in the 24 hours terminating at 5 p. m. on January 16, 1921, was only 12 inches and not 20 inches. Consequently the illustration is at fault and should be ignored.

However, on the same day 20.15 inches of rain fell at Maunawilli Ranch about 2 miles to the east on the windward side of the mountain.

Furthermore, on November 18, 1930, an automatic recorder belonging to the Geological Survey and situated in Moanalua Valley measured 15.2 inches of rain in three hours and 5.6 inches in one hour.

Based on this rain, the value of C in the appropriate formula should be taken at 5.6 and the probable maximum rain in any single minute was $5.6=\sqrt[3]{0.0167}=1.4$ inches.

[4] Supplement to article in the MONTHLY WEATHER REVIEW for October, 1930.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Abbot, C. G.
Weather dominated by solar changes. Washington. 1931. 18 p. figs. 24½ cm. (Smith. misc. coll., v. 85, no. 1.)

Curry, Manfred.
Wind and water. London. [1930.] 28, 14 p. plates. 30½ cm.

Elm, Ienar Ewald.
Weather and why; an aviator's presentation of aeronautical meteorology . . . Philadelphia. [c1929.] 109 p. front. illus. plates. diagrs. 21½ cm.

Gillette, Halbert P.
Electrodynamic theory of cyclones and anticyclones. p. 22–23. 29½ cm. (Water works and sewerage. v. 78, Jan., 1931.)

Jaumotte, J.
Un nouveau météorographe pour ballon-sonde. Bruxelles. 1930. 44 p. figs. 29½ cm. (Inst. roy. mét. de Belgique. Mém. v. 3.)

Köppen, W., & Geiger, R., *comp.*
Handbuch der Klimatologie. Berlin. 1930. Bd. 1. Teil A, D, E. Bd. 2. Teil G.

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Verbessertes Graukeilphotometer. [2 p.] 24 cm. (Ztschr. für wissensch. Bäderkunde. 1930. H. 11.)

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Klima und Boden in ihrer Wirkung auf das Pflanzenleben. Zweite, verb. Aufl. Jena. 1930. x, 480 p. illus. maps. diagrs. 24 cm.

Maguire, Charles Joseph.
Aerology; a ground school manual in aeronautical meteorology. 1st ed. New York. 1931. xii, 136 p. illus. maps (part fold.) diagrs. 23½ cm.

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Der feuchtlabile Niederschlag. Oslo. 1930. 71 p. figs. 31 cm. (Geofysiske publ. v. 5, no. 12.)

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Le paratonnerre dans les missions et aux colonies. [Bruxelles.] n. d. 32 p. figs. 17½ cm. (Extr.: Rev. miss. des Jésuites belges, Louvain.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS, FEBRUARY, 1931

By HERBERT H. KIMBALL

For a description of instruments employed and their exposures, the reader is referred to page 41 of this volume of the REVIEW.

Table 1 shows that solar radiation intensities averaged above the normal intensity for February at Washington, D. C., and below normal at Madison, Wis., and Lincoln, Nebr. Both these stations reported much dense local smoke during the month.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at Lincoln, Chicago, and New York, and a deficiency at all other stations, which was pronounced at Fresno and Pittsburgh.

Skylight polarization measurements were obtained at Washington on seven days, and give a mean percentage of 61, with a maximum of 64 on the 25th. These are close to the corresponding averages for Washington in February. No measurements were obtained at Madison during this month, as the groundwas continuously covered with snow.

TABLE 1.—*Solar radiation intensities during February, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass, A. M.					Air mass, P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Feb. 3	1.60	0.76	0.90	1.05			1.26	1.04	0.88	0.74	2.06
Feb. 4	3.45						1.14	1.05	0.89	0.69	4.37
Feb. 5	2.49	0.78	0.94	0.97	1.17			1.02	0.80	0.70	2.16
Feb. 10	2.36	0.83	0.94	1.06	1.26						1.78
Feb. 11	1.45	0.85	0.93	1.00	1.19		1.13	0.95	0.86	0.75	1.37
Feb. 24	3.63						1.15				2.74
Feb. 25	2.49	0.90	1.07	1.25	1.27		1.33	1.05	0.87		2.49
Feb. 26	3.30		1.01	1.14	1.28						2.36
Feb. 27	2.62	0.87	0.99	1.15	1.27		1.20	0.98	0.82		1.96
Means		0.83	0.97	1.09	1.21		1.20	1.02	0.85	0.72	
Departures		+0.11	+0.16	+0.11	+0.07		+0.01	+0.04	+0.01	−0.01	

TABLE 1.—*Solar radiation intensities during February, 1931*—Con.

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass, A. M.					Air mass, P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Feb. 4	3.30	1.08	1.10	1.26	1.16						3.00
Feb. 5	3.30	0.69	0.83	0.97	1.25		1.16	1.01			3.63
Feb. 10	1.37	0.65	0.77	0.98	1.23		1.26	0.72			1.60
Feb. 11	2.87						1.15				3.45
Feb. 13	2.62	1.00	1.11	1.24	1.43	1.64	1.46				1.37
Feb. 14	1.12	1.05	1.11	1.29	1.41		1.35				1.24
Feb. 21	3.81		0.55	0.79	1.11						3.63
Feb. 25	4.75						1.36	1.21			3.63
Feb. 26	3.45	0.97	1.09	1.22	1.41	1.60	1.34				2.36
Means		0.91	0.94	1.11	1.29	(1.62)	1.30	0.98			
Departures		−0.03	−0.11	−0.09	−0.07		−0.06	−0.19			

Lincoln, Nebr.

Date	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
Feb. 2	3.81	0.55	0.56		1.37		1.35	1.23	1.10	0.96	5.16
Feb. 3	4.37	0.95	1.09	1.24	1.38		1.35	1.20	1.09		4.37
Feb. 11	3.63		0.85	0.99	1.26						4.17
Feb. 14	1.32	0.85	0.99	1.18	1.31		1.33	1.15	0.96	0.77	1.68
Feb. 19	3.45						1.22	1.03			3.63
Feb. 20	3.15	0.60	0.74	0.88	1.08						3.81
Feb. 27	5.36		0.67	0.78	1.25						4.57
Means		0.74	0.82	1.01	1.28		1.31	1.15	1.05	(0.86)	
Departures		−0.17	−0.20	−0.17	−0.09		−0.04	−0.01	+0.02	−0.06	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
	Average daily totals										
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 29	217	160	290	135	170	----	119	316	182	206	240
Feb. 5	195	209	291	129	135	----	142	341	245	250	305
Feb. 12	220	218	260	150	154	----	115	311	280	251	300
Feb. 19	226	244	256	142	228	----	106	314	407	334	222
	Departures from weekly normals										
Jan. 29	+17	−30	+59	+16	+29	----	−6	+11	−38	−36	----
Feb. 5	−7	±0	+29	+5	−2	----	+1	+34	−54	+6	----
Feb. 12	−6	−10	−20	+10	+4	----	−39	−8	−56	−24	----
Feb. 19	−29	−6	−45	−22	+44	----	−40	−52	+54	+10	----
Accumulated departures on Feb 26	+280	−966	+560	+126	+1,050	----	+21	−77	−350	+154	----

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1931	*h* *m*	°	°	°			
Feb. 1 (Naval Observatory)	11 9	No spots					
Feb. 2 (Naval Observatory)	11 41	−80.0	213.4	+10.0		62	62
Feb. 3 (Naval Observatory)	11 38	−65.0	215.3	+10.5		231	
		−44.5	235.8	−10.5	6		237
Feb. 4 (Naval Observatory)	11 38	−50.0	217.1	+9.5		154	
		−28.0	239.1	−12.0	9		
		+68.0	335.1	+8.0		12	175
Feb. 5 (Naval Observatory)	11 44	−38.0	215.9	+10.0		201	
		−12.0	241.9	−12.5	3		204
Feb. 6 (Naval Observatory)	11 46	−23.5	217.2	+10.0		262	
		−10.5	230.2	−31.5	3		265
Feb. 8 (Yerkes Observatory)	16 6	+5.3	217.3	+8.9		326	
		+4.0	216.0	+10.0	102		428
Feb. 9 (Mount Wilson)	11 30	−89.0	112.3	+8.0	16		
		+16.0	217.3	+9.0		214	
		+41.0	242.3	−16.0		8	
		+55.0	256.3	−14.0		18	256
Feb. 10 (Naval Observatory)	11 51	+30.0	218.0	+9.0		108	
		+87.5	275.5	−12.5		62	170
Feb. 11 (Naval Observatory)	12 28	−63.0	111.5	+9.0		15	
		+45.0	219.5	+5.0		62	77
Feb. 12 (Naval Observatory)	12 46	−45.0	116.1	+8.0		62	
		+59.0	220.1	+5.0	46		108
Feb. 13 (Yerkes Observatory)	12 34	−35.0	113.1	+6.3		52	
		−30.2	117.9	+6.2		57	
		+67.8	215.9	+7.7	82		191
Feb. 14 (Naval Observatory)	12 43	−80.0	54.8	+0.1	15		
		−79.0	55.8	+8.5	12		
		−18.0	116.8	+4.0		59	86
Feb. 15 (Naval Observatory)	11 32	−70.0	52.3	+9.0		46	
		−66.0	56.3	+0.1		46	
		−10.0	112.3	−7.5		25	
		−2.0	120.3	+4.0	6		
		+4.5	126.8	+3.0	3		
		+12.0	134.3	+10.5	6		132
Feb. 16 (Naval Observatory)	14 39	−57.5	49.9	−16.0		62	
		−50.0	57.4	−22.0		77	
		+15.0	122.4	+8.0	12		
		+18.0	125.4	+11.0	15		166
Feb. 17 (Mount Wilson)	13 50	−42.5	52.2	+6.0		219	
		−37.5	57.2	−4.0		147	
		+42.0	136.7	+12.0		103	469
Feb. 18 (Mount Wilson)	13 55	−27.5	54.0	+6.0		349	
		−24.0	57.5	−3.0	149		
		+57.0	138.5	+12.0		31	529

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1931	*h* *m*	°	°	°			
Feb. 19 (Mount Wilson)	13 15	−14.5	54.2	+6.0		1,265	
		−10.0	58.7	−3.0		153	
		0.0	68.7	+9.0		71	
		+67.0	135.7	+12.0		4	1,493
Feb. 20 (Mount Wilson)	14 10	+1.0	56.0	+7.0		1,571	
		+4.0	59.0	−3.0		42	
		+15.0	70.0	+9.0		40	1,653
Feb. 21 (Naval Observatory)	12 39	+15.0	57.7	−7.0		123	
		+17.5	60.2	+5.0		1,389	
		+28.0	70.7	+7.5		77	1,589
Feb. 22 (Naval Observatory)	11 37	−45.0	75.0	+12.5		247	
		+26.0	56.0	−5.0		370	
		+28.0	58.0	+5.5		1,389	
		+40.0	70.0	+7.5		15	2,021
Feb. 23 (Naval Observatory)	12 5	−65.0	311.7	+10.0		77	
		−30.0	346.7	+13.5		154	
		+40.0	56.7	−5.5		463	
		+42.0	58.7	+7.5		1,080	1,774
Feb. 24 (Naval Observatory)	11 33	−50.0	313.8	+11.0		77	
		−16.0	347.8	+12.5		185	
		+53.0	56.8	−5.0		309	
		+55.0	58.8	+7.0		926	1,497
Feb. 25 (Naval Observatory)	12 12	−85.0	265.3	−3.5		62	
		−38.0	312.3	+1.5		93	
		−1.0	349.3	+11.5		185	
		+26.0	16.3	+10.5	6		
		+67.0	57.3	−6.5		216	
		+68.0	58.3	+6.0		525	1,087
Feb. 26 (Naval Observatory)	11 33	−69.0	268.4	−4.0		154	
		−45.0	292.4	+10.0		93	
		−22.0	315.4	+9.0	9		
		+13.0	350.4	+10.5		154	
		+38.0	15.4	+9.5		62	
		+77.0	54.4	+6.0		216	
		+80.0	57.4	−7.0		247	935
Feb. 27 (Naval Observatory)	11 37	−55.0	269.2	−4.0		154	
		−31.0	293.2	−10.5	3		
		−30.0	294.2	+9.0		62	
		−5.0	319.2	+8.0	6		
		+22.0	346.2	+11.5		46	
		+29.0	353.2	+8.0	12		
		+52.0	16.2	+8.5		31	314
Feb. 28 (Naval Observatory)	11 32	−40.0	271.1	−5.0		247	
		+4.0	315.1	+9.0	3		
		+42.0	353.1	+7.5	9		
		+63.0	14.1	+9.0	31		290
Mean daily area for February							600

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR FEBRUARY, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

February, 1931	Relative numbers	February, 1931	Relative numbers	February, 1931	Relative numbers
1	0	11	20	21	96
2	8	12	Ec 20	22	
3	d 28	13	23	23	100
4		14	Ecd 19	24	92
5	25	15	41	25	a 68
6	29	16	44	26	d 82
7	19	17		27	72
8	a 27	18	45	28	47
9	29	19			
10	28	20	ab		

Mean: 23 days=41.8.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures during February were considerably above normal at all levels at Ellendale, the northernmost station. (See Table 1.) Positive departures of appreciable magnitude occurred also at Royal Center and Broken Arrow. Negative departures occurred at all levels at Due West and in the higher levels at Groesbeck.

Free-air relative humidities were considerably above normal at Broken Arrow, especially in the higher levels. This fact together with the positive temperature and vapor pressure departures at this station are of special significance in view of the appreciable excess over normal of the total precipitation for the month. Free-air vapor pressures averaged mostly above normal at the other stations excepting Due West.

The resultant free-air wind directions at the 1,000-meter level were mostly northwesterly east of the Rocky Mountains except in the extreme south where they were southerly. Along the North Pacific coast they were variable with a southerly component predominating at the more northerly stations.

At 3,000 meters the resultant direction was strikingly uniform from the west-northwest at practically all stations in the country with a marked northerly component at San Francisco and Modena.

Free-air resultant velocities decreased from the northern to southern stations with lowest values in the Rocky Mountain region.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during February, 1931*

TEMPERATURE (°C.)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.6	+1.7	5.8	−2.0	−3.1	+6.6	12.0	+2.2	1.5	+3.0
500	6.3	+2.5	6.3	−0.8	−3.2	+6.5	10.8	+2.2	0.0	+3.5
1,000	5.6	+2.6	4.9	−0.6	−1.8	+6.8	8.5	+0.2	−1.8	+2.7
1,500	3.4	+1.3	2.8	−0.8	−2.7	+5.4	6.5	−0.6	−2.3	+3.1
2,000	1.1	+0.6	0.9	−0.8	−4.5	+5.0	4.8	−0.3	−3.8	+3.0
2,500	−1.2	+0.6	−1.5	−0.8	−6.9	+4.9	2.0	−0.7	−5.7	+3.0
3,000	−3.4	+1.0	−4.1	−0.9	−9.8	+4.7	−4.4	−4.7	−7.8	+3.4
4,000	−10.2	−0.6	−10.7	−1.7	−15.4	+4.4	−9.9	−5.4	−12.9	+4.3
5,000	−16.4	−1.1	----	----	−21.7	+3.9	----	----	−19.4	----

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during February, 1931*—Continued

RELATIVE HUMIDITY (%)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Elleudale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	75	+6	76	+7	82	+1	80	+6	78	0
500	68	+2	68	+4	81	+1	76	+8	76	−2
1,000	62	+5	64	+4	63	−7	71	+13	73	+3
1,500	63	+12	60	+4	53	−9	65	+14	57	−5
2,000	62	+16	50	−3	50	−9	56	+10	54	−2
2,500	59	+15	44	−7	49	−10	53	+9	53	−1
3,000	56	+13	46	−3	49	−9	49	+7	55	0
4,000	57	+16	46	0	36	−19	42	+5	57	0
5,000	55	+16	------	------	34	−24	------	------	58	------

VAPOR PRESSURE (*mb.*)

Altitude m. s. l. (meters)	Broken Arrow, Okla.		Due West, S. C.		Elleudale, N. Dak.		Groesbeck, Tex.		Royal Center, Ind.	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	7.51	+1.27	7.28	−0.62	4.14	+1.55	11.29	+1.80	5.34	+0.82
500	6.73	+1.25	6.85	−0.19	4.01	+1.47	9.99	+1.85	4.70	+0.77
1,000	5.81	+1.42	5.79	−0.23	3.37	+1.05	8.08	+1.48	3.88	+0.66
1,500	5.05	+1.47	4.64	−0.22	2.63	+0.56	6.49	+1.34	2.94	+0.40
2,000	4.13	+1.31	3.29	−0.50	2.18	+0.45	4.95	+0.94	2.53	+0.52
2,500	3.36	+1.04	2.36	−0.57	1.78	+0.36	4.14	+0.90	2.14	+0.48
3,000	2.90	+1.01	2.05	−0.21	1.40	+0.29	3.56	+0.88	1.87	+0.53
4,000	1.92	+0.61	1.67	+0.43	0.50	−0.17	2.92	+1.16	1.50	+0.67
5,000	1.14	+0.34	----	----	0.16	−0.22	------	------	1.24	------

TABLE 2.—*Free-air data obtained by airplanes at naval air stations during February, 1931*

Altitude, m. s. l. (meters)	Temperature (°C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	2.2	9.8	15.0	−0.5	68	82	65	79
500	2.4	10.3	13.5	1.4	57	73	65	60
1,000	0.9	7.7	11.2	−0.3	47	76	62	54
2,000	−0.9	4.0	5.2	−3.5	28	59	55	45
3,000	−4.4	−0.6	0.7	−7.5	18	46	38	55

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during February, 1931*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 31 E	1.0	S 40 E	0.7	S 16 W	0.7	N 78 W	2.6	N 33 E	0.8	N 67 W	1.3
500	S 16 E	3.7	S 51 E	4.3	S 85 W	2.4	--------	----	N 22 W	0.8	N 63 W	1.8
1,000	S 43 W	3.6	S 9 E	4.8	N 80 W	5.4	--------	----	N 78 W	3.0	N 62 W	4.4
1,500	S 86 W	3.1	S 28 W	4.9	N 44 W	7.4	--------	----	N 75 W	4.4	N 67 W	6.0
2,000	S 89 W	3.9	N 89 W	2.5	N 36 W	10.7	N 76 W	4.1	N 68 W	6.3	N 67 W	6.8
2,500	N 86 W	4.0	N 64 W	7.2	N 38 W	11.8	N 73 W	5.8	N 65 W	7.7	N 61 W	8.4
3,000	N 61 W	3.5	N 77 W	6.8	N 43 W	13.6	N 71 W	5.8	N 71 W	9.7	N 51 W	9.9
4,000	--------	----	--------	----	--------	----	N 70 W	6.1	N 72 W	14.6	N 80 W	10.1
5,000	--------	----	--------	----	--------	----	N 47 W	2.9	N 82 W	18.5	--------	----

Altitude, m. s. l. (meters)	Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 7 E	0.6	S 60 W	2.5	N 34 W	0.9	N 52 E	2.0	N 51 E	2.3	S 5 E	0.3
500	S 34 W	1.9	--------	----	S 53 E	0.7	N 74 E	3.5	S 78 E	3.6	N 54 E	0.2
1,000	S 80 W	2.5	S 69 W	6.4	S 68 W	1.9	S 54 E	2.6	S 63 E	2.9	S 5 W	1.4
1,500	N 71 W	1.5	S 86 W	7.8	N 87 W	2.7	S 53 W	1.8	S 49 E	2.0	S	2.6
2,000	N 69 W	2.9	N 84 W	7.7	N 80 W	5.0	S 85 W	3.6	S 73 E	1.6	S 52 W	2.9
2,500	N 64 W	4.2	N 77 W	6.8	N 89 W	7.8	N 81 W	5.1	N	3.6	S 62 W	4.1
3,000	N 76 W	7.5	N 82 W	5.4	N 70 W	7.7	N 76 W	5.2	--------	----	S 75 W	3.1
4,000	N 88 W	9.9	--------	----	N 73 W	13.0	N 85 W	10.0	--------	----	N 81 W	2.5
5,000	--------	----	--------	----	--------	----	N 89 W	13.6	--------	----	--------	----

Table 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during February, 1931*—Continued.

Altitude (meters) m. s. l.	Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Royal Center, Ind. (225 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 63 E	0.4	N 69 W	0.2	N 65 E	0.9	S 51 E	1.1	S 76 E	2.8	S 88 W	0.4
500	N 36 W	1.4	----	----	S 59 E	2.0	S 19 W	1.6	S 73 E	2.6	N 63 W	3.3
1,000	N 45 W	4.0	----	----	N 84 W	2.2	S 78 W	3.6	S 48 E	0.7	N 48 W	5.3
1,500	N 41 W	5.8	----	----	N 68 W	3.5	N 76 W	5.1	S 19 E	1.5	N 60 W	7.4
2,000	N 51 W	5.8	N 32 E	1.6	N 73 W	4.2	N 62 W	5.7	S 11 W	2.2	N 62 W	8.9
2,500	N 38 W	5.6	N 53 E	1.8	N 58 W	4.4	N 68 W	6.2	S 40 W	2.6	N 64 W	8.9
3,000	----	----	N 8 W	1.4	N 82 W	6.2	N 70 W	7.8	S 76 W	2.5	N 74 W	8.2
4,000	----	----	N 59 W	4.7	----	----	N 76 W	8.8	N 88 W	4.9	----	----
5,000	----	----	N 34 W	7.4	----	----	----	----	----	----	----	----

Altitude (meters) m. s. l.	Salt Lake City, Utah (1,294 meters)		San Francisco, Calif. (8 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Spokane, Wash. (606 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 55 E	0.5	N 80 E	1.2	N 61 W	0.5	S 38 E	0.9	S 12 E	1.0	N 24 W	1.0
500	----	----	N 11 E	1.6	N 9 W	1.6	S 2 W	4.7	----	----	N 46 W	5.9
1,000	----	----	N 3 E	1.9	N 34 W	5.0	S 20 W	4.4	S 2 E	2.5	N 52 W	8.3
1,500	S 37 E	1.0	N 47 W	1.0	N 33 W	6.0	S 35 W	4.8	S 36 W	3.7	N 56 W	11.0
2,000	S 3 E	2.1	N 16 W	3.5	N 32 W	8.4	S 22 W	4.4	S 49 W	3.4	N 50 W	10.9
2,500	S 31 W	1.8	N 18 W	5.3	N 39 W	11.7	S 50 W	3.4	S 54 W	4.0	N 51 W	12.2
3,000	S 77 W	1.4	N 34 W	5.4	N 41 W	11.2	----	----	S 72 W	4.0	N 59 W	11.0
4,000	S 53 W	3.8	----	----	----	----	----	----	S 23 W	4.0	----	----
5,000	----	----	----	----	----	----	----	----	----	----	----	----

Table 4.—*Observations by means of kites, captive and limited height sounding balloons during February, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, meters m. s. l., reached during month	2,822	2,636	3,193	2,492	2,852
Maximum altitude, meters m. s. l., reached	5,416	4,149	5,197	4,560	5,352
Number of flights made	28	30	26	19	27
Number of days on which flights were made	26	28	25	19	26

In addition to the above, there were approximately 176 scheduled pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. Bennett

GENERAL SUMMARY

February was much warmer than normal in nearly all sections of the country. Along the Atlantic and Gulf coasts temperatures were near the average, but in Florida they were slightly below. In the Ohio Valley the month averaged from 4° to 8° warmer than normal, the central Mississippi Valley from 8° to 11° warmer, and from Iowa and Nebraska northward and northwestward, the plus departures were from 12° to more than 20°.

The precipitation during the month was very unevenly distributed. A large portion of the Southeast received less than half the normal. Light amounts fell also over a belt from the western lake region westward to South Dakota, and in much of the northern Rocky Mountain and the Pacific regions, while the northern portion of the Ohio Valley received from 60 to 75 per cent of normal. Generous amounts were received from southern Missouri, Oklahoma, and the central Rocky Mountain region southward, while the far Southwest received abnormally heavy rains.

TEMPERATURE

The temperature conditions were much like those of January just preceding, but usually February was still warmer than January had been. The first six days of February greatly resembled the last few of January, temperatures being below normal in parts of the Northeast, and about normal in Florida, while some cool weather occurred in the far Northwest; but for most of the country the warmth was noteworthy and very unseasonable, two stations in North Dakota averaging 34° warmer than normal for the week ending February 3.

A cold spell, not severe, appeared about the 8th in the far Northwest, yet was mainly of brief duration, save that after it had spread southward and eastward the southeastern portion of the country was mainly cooler than normal until about the 20th. Meantime, moderately cool weather had set in over the southern Plateau region. The last week was generally cooler than normal in southern sections from New Mexico to the south Atlantic coast, particularly in Texas; but central and northern sections had mild weather for the season all the second half of February, especially the districts between the Lakes and the northern Rocky Mountains.

While February as a whole was decidedly mild in most States, the temperatures were comparatively steady from day to day, with few new records established. The highest marks were generally noted about the 8th in the lower Mississippi Valley and in central sections east of that river, but on the 28th from Michigan and Ohio eastward; while west of the Mississippi River they occurred mainly during the first five days or about the 19th. The lowest readings occurred usually from the 7th in the Pacific Northwest to the 11th in the Atlantic and Gulf States; but in the middle and southern Rocky Mountain region and to westward at various dates.

Of the 37 States from the Plains eastward only 15 recorded temperatures below zero at any time during February, 1931.

Chart No. 1 shows the distribution of mean temperature with respect to the normal.

Much of the upper Missouri Valley found this the warmest February in the whole period of records, which at a few points exceeded 50 years in length.

For most of the central and north-central portions of the country the 3-month winter period, December, 1930, to February, 1931, averaged warmer than, or about equal to, the warmest other like period of record. At St. Paul, Minn., in a record covering 111 consecutive winters, only that of 1877–78 surpassed the mildness of the winter just ended.

PRECIPITATION

The fortnight from the 3d to the 16th was notable for heavy precipitation for the region over most of southern California and Arizona. During the same time well-distributed moderate to heavy rain reached most of the near Southwest, the central valleys and the southern drainage of the Ohio River. Several scattered areas received much precipitation during the last three days of the month.

February, as a whole, brought considerably more moisture than January had, yet for more than half of the country there was less than normal. In many eastern and central districts the precipitation was well distributed through the month and fell at a gentle to moderate rate, the soil thus getting great benefit for the quantity. The inset on Chart No. V shows the monthly distribution with respect to the normal.

At Cairo, Ill., and Springfield, Mo., the monthly amounts were greater than normal for the first time since January, 1930.

The precipitation of the past winter (December to February, inclusive) is noted as the least of any winter of record at several places in the north-central portion of the country; likewise at some localities in northern California.

SNOWFALL

The snowfall was usually light for February, save in a few States. The middle and southern portions of the Rocky Mountain area mainly had more than normal, while from central North Dakota eastward to New England, the more northern States usually had from one-half to seven-eighths of normal amounts.

The snowfall was light and largely negligible over the southern half of the Middle Atlantic States, practically all of the Ohio Valley, the middle and much of the upper Mississippi Valley, and almost all the Plains. Most of Montana received but very light snowfall, while the Plateau and Pacific States nearly everywhere received much less than normal. When February ended, the stored snow in the elevated portions of the West was in almost every area less than the average quantity and in several States about as little as had ever before been noted at this time of year.

SUNSHINE AND RELATIVE HUMIDITY

Throughout much of the East and Southeast, and the northern portions of the Great Plains more than the normal amount of sunshine was received during the month, while in the Southwest and central Rocky Mountain region and to the westward, much cloudy weather prevailed. Elsewhere, about the usual amount of sunshine was received. The relative humidity was below the normal generally in the Southeast, much of the East, the Missouri Valley and far Northwest, while in the Southwest and the central and southern portions of the Rocky Mountain and Plateau regions it was above normal. The plus departures were rather large in the far Southwest, as would be expected from the abnormal rainfall received in that region.

SEVERE LOCAL STORMS, FEBRUARY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, miles	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
El Dorado, Kans	6	10 a. m.	2			Heavy hail	Some damage to wheat; path 14 miles long	Official, U. S. Weather Bureau.
Toledo, Ohio	7	3 a. m.-1:15 p. m.				Ice	Minor damage to trees and wires	Do.
Iowa (southern)	7					Blizzard	Numerous automobile accidents; motor and rail transportation interrupted.	Do.
Canaveral Lighthouse, Fla. (near).	17				$8,000	Winds	4 fishing boats beached	Do.
Sealy, Tex	28	7 p. m.	4		1,500	Hail	Crops injured	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

There were no overflows of importance in February, 1931. In Georgia, especially during the latter half of the month, there was enough rain to cause pronounced rises in the rivers, but bankful stages were not reached and the rises were quite beneficial. Rains in southwestern Missouri and northwestern Arkansas were rather heavy on the 7th and 8th and caused bankful stages in the Black, White, and Petit Jean Rivers. In eastern Texas, also, there was enough rain to materially increase the volume of water carried by the rivers, and at a few places the Trinity overflowed very slightly, without causing any damage. Probably the rises of the greatest importance occurred in Arizona, and are reported by the official in charge of the Weather Bureau office at Phoenix as follows:

As a result of heavy rains in southern Arizona from the 11th to the 16th, flashy rises occurred at a number of places in tributaries of the Gila River and at headwaters of that stream. The Salt River at Phoenix attained a stage of 6.2 feet on the 15th and continued above flood stage, 5.0 feet, on the 16th, the stage on the morning of the 16th being 5.3 feet. The greater part of the water came from the Verde River, a tributary of the Salt. Very little water was received from the Salt, owing to the storage dams on that stream.

Heavy rains in the drainage area of the San Pedro, a tributary of the upper Gila, caused a considerable rise at Kelvin (a short distance below the Coolidge Dam), which reached a height of 6.5 feet on the 16th; after this there was a rapid fall. The flood stage at Kelvin is 5.0 feet.

As little water came from the Hassayampa River, and the greater part of that from the Agua Fria was impounded by the Pleasant Irrigation Dam, there was no marked rise in the lower Gila.

Two men were drowned in the Verde River by the overturning of a boat. Unusually heavy rain at Wellton, near Yuma, was followed by a rush of water from a "wash" near that place. A trestle and some of the roadbed of the Southern Pacific Railway were carried out, causing damage to the extent of about $30,000.

A table of flood stages and crests is given below.

In most of the Mississippi system low river stages still prevail. Usually, low February levels above Cairo are caused by ice, but in the winter just ending there has been less ice than is customary. At Sioux City, Iowa, the channel of the Missouri was not closed at any time. The Sioux City records extend to 1855, and at only one other time, in 1888-89, did the channel remain open through the winter. Early in February the ice had run out of the Missouri as far north as Chamberlain, S. Dak.

The following reports from officials in charge of Weather Bureau offices are considered of interest:

Pittsburgh, Pa.—Precipitation during February was light, but was sufficient during the second and third weeks to create considerable run-off. The smaller tributaries were running strong for several days, and the Ohio at Pittsburgh rose to a stage of 14.4 feet on the 21st—the highest stage since April 23, 1930. Wells, springs, and some small streams that dried up during the fall are running again.

Cincinnati, Ohio.—For the last three months—November, December, and January—the rainfall in and around Cincinnati actually was less than the normal January rainfall alone. This emphasizes the increasing gravity of the situation.

Farmers right now are hauling more water for their suffering stock, and for themselves, than they hauled at the peak of the drought last summer.

Hamilton County commissioners have been informed within the last week that tank wagons are carrying 50,000 gallons of water a day from the county pipe lines to farms and residences without water. An increase to 60,000 gallons daily is imminent.

Memphis, Tenn.—Rivers here are already feeling the effects of the dry weather. The Mississippi River is the lowest in the past 12 years and cargo barges are having difficulty in negotiating narrows and shallows. A majority of the river firms have been loading their barges only to half capacity in order to insure swift and safe trips.

Table of flood stages in February, 1931

River and station	Flood stage	Above flood stage—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI DRAINAGE	*Feet*			*Feet*	
Black: Black Rock, Ark	14.0	9	10	15.6	10
White: Batesville, Ark	23.0	9	10	23.8	10
Petit Jean: Danville, Ark	20.0	10	11	20.8	11
		15	16	20.7	15
		24	25	21.3	24
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex	28.0	25	26	29.4	26
Liberty, Tex	25.0	12	12	25.2	12
PACIFIC DRAINAGE					
Gila: Kelvin, Ariz	5.0	15	16	6.5	16
Salt: Phoenix, Ariz	5.0	15	16	6.2	15

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

February is normally one of the stormiest months of the year over the North Atlantic, and the conditions during the current month could not be called exceptional, although there were a number of severe disturbances that will be referred to later. The number of days with gales was not far from normal west of the fortieth meridian, north of the thirtieth parallel, and somewhat below over the middle and eastern sections of the steamer lanes. The North Atlantic HIGH was unusually well developed, as indicated by the large positive departure at Horta, shown in Table 1.

Fog was much more prevalent than during the preceding two months, and the number of days on which it was reported in different localities is as follows. Over the Grand Banks, from 6 to 12 days; along the American coast, between the thirtieth and forty-fifth parallels, from 2 to 5 days; over the steamer lanes between the twentieth and forty-fifth meridians, from 1 to 5 days; along the European coast, from 1 to 3 days; in the Gulf of Mexico, from 1 to 2 days.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean February, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.66	(1)	30.46	27th	29.06	3d.
Belle Isle, Newfoundland	29.87	+[2]0.12	30.66	19th	29.34	28th.
Halifax, Nova Scotia	29.87	−[3]0.04	30.52	8th	29.32	23d.
Nantucket	29.96	−[3]0.04	30.42	7th	29.64	14th.
Hatteras	30.07	−[3]0.04	30.30	12th	29.82	14th.
Key West	30.03	−[3]0.07	30.20	7th	29.82	25th.
New Orleans	30.07	−[3]0.06	30.30	15th	29.76	24th.
Cape Gracias, Nicaragua	29.93	−[2]0.06	29.98	13th [4]	29.86	16th.
Turks Island	30.04	−[2]0.04	30.16	7th [4]	29.84	4th.
Bermuda	29.95	−[3]0.17	30.38	13th	29.30	26th.
Horta, Azores	30.41	+[2]0.28	30.78	12th	30.08	22d.
Lerwick, Shetland Islands	29.54	−[2]0.18	30.32	3d	28.91	20th.
Valencia, Ireland	29.98	+[2]0.08	30.32	3d [4]	29.59	8th.
London	29.92	−[2]0.08	30.37	24th	29.22	16th.

[1] No normal available.
[2] From normal shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

On the 1st a fairly deep depression was central near the south coast of Greenland, with a secondary LOW over the North Sea, and moderate gales prevailed over the central section of the steamer lanes and off the west coasts of France and England.

On the 3d there was evidently a redevelopment of the Greenland LOW, and on that date moderate to strong westerly gales occurred in the southerly quadrants. This LOW moved slowly eastward, and on the 5th was central near 52° N., 22° W.

A moderate depression that on the 7th was over the eastern section of the steamer lanes developed into a severe disturbance, as on the 8th vessels near the center reported westerly winds of hurricane force. On the 9th and 10th stormy conditions continued over the central section of the ocean, and on the latter date as well as on the 11th northerly gales were reported west of the seventieth meridian, between the twenty-fifth and fortieth parallels, and from the 10th to 12th heavy weather was also encountered off the west coast of Europe.

On the 13th and 14th moderate conditions prevailed over the ocean as a whole, with the exception of gales over a limited area about 500 miles east of the Bermudas, while on the 13th land stations on the British Isles reported northerly winds of force 7 and 8.

On the 15th Sydney, Nova Scotia, was near the center of a well-developed LOW, and on the same date a secondary was over the Bermudas, while severe gales were encountered by vessels in the intermediate region. According to press reports three vessels were beached, one sunk, and others damaged in the vicinity of Hampton Roads during the storm.

On the 16th and 17th strong to whole northerly gales again prevailed along the coast of Europe, the storm area extending from the forty-fifth to fifty-seventh parallels, while moderate conditions were the rule over the remainder of the ocean.

On the 18th a depression was central about midway between the Azores and Bermudas that increased in intensity as it moved slowly eastward, and on the 19th and 20th gales of force 8 to 10 were encountered by vessels between the thirtieth and fortieth meridians. On the 20th northwesterly gales also occurred over the eastern section of the northern steamer lanes.

Charts VIII and IX show the conditions on the 22d and 23d, respectively, when a very severe and extensive disturbance prevailed over the western section of the ocean. By the 24th this storm had decreased considerably both in extent and intensity, and on the 25th moderate weather prevailed generally.

On the 26th Bermuda was near the center of a LOW that developed into a severe disturbance as shown on Charts X and XI for the 27th and 28th, respectively.

NOTES.—Canadian steamship *City of Vancouver*, Capt. M. Buchanan; Observer, W. A. Kent; from Antwerp to Canal Zone; Feb. 4, 1.45 A. T. S. in 14° 52′ N., 72° 44′ W. Sea appeared to have on a fine layer of dust with occasional irregular lines of what appeared to be yellow sand. These stretched approximately in a north and south direction and extended as far as could be seen on both sides. These conditions continued until about 3 p. m. in 14° 45′ N., 72° 53′ W. Course, S. 52° W.; windW. S. W., 2; sea slight; swell, easterly, slight; barometer, 29.94 inches; thermometer, 83°; sea temperature, 79.5°.

Mr. C. Desmond, second officer and observer, Honduran steamship *Cuyamapa*, Capt. N. Christiansen, reports as follows:

At 19.55 G. M. T. I observed an exceptionally large waterspout several hundred feet high in latitude 30° 58′ N., longitude 77° 18′ W.

It formed very quietly, no confusion or vapor in vicinity except in itself. It ascended in a straight line, or nearly so, towards the sky to a great height. When heavy dark blue sky lowered in a cone-shape form until it met the ascending water or vapor.

In the center of the globular-shaped moisture, a very light tube formed and continued for 20 minutes. Then it separated at an altitude of a thousand feet, lowered to approximately 500 feet, and took the form of a burning mountain.

With great force these fumes took altitude. The spout, later losing its energy turned to a whirlwind of great interest, about 5 to 10 feet above the surface.

Later heavy showers of rain fell; the wind increased to force 5, veering to the west and northwest, that had been southerly. Barometer, 29.58; air, 66° F.; surface temperature of sea water 71°.

OCEAN GALES AND STORMS, FEBRUARY, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Frederik VIII, Dan. S. S.	Oslo	Halifax	56 35 N	28 20 W	Feb. 2	Mdt, 2	Feb. 4	29.47	SSE	SSE, 8	WSW	WSW, 10	SSE-S-SSW.
Milwaukee, Ger. M. S.	New York	Galway	49 45 N	30 00 W	Feb. 3	10 p, 4	Feb. 5	29.47	E	SSW, 10	NW	WNW, 11	E-S-W-NW.
Carlsbolm, Swed. S. S.	Fair Island Strait.	Boston	57 59 N	22 24 W	Feb. 4	7 a, 5	do	29.19	W	SSW, 6	WSW	WSW, 12	SE-SW-N.
Ala, Am. S. S.	Antwerp	New York	39 14 N	55 50 W	Feb. 5	1 p, 6	Feb. 6	29.59	S	SSW, 8	NW	S, 9	S-W-NW.
Sinaia, Fr. S. S.	Gibraltar	Providence	39 00 N	42 05 W	do	—, 7	Feb. 8	29.60	SW	Calm	NNE	SSW, 10	
Carlsholm, Sweden	Fair Island Strait.	Boston	54 20 N	36 08 W	Feb. 8	8 a, 8	do	28.70	WSW	WSW, 11	W	WSW, 12	SW-W-NW.
Jean Jadot, Belg. S. S.	New York	Antwerp	41 05 N	50 28 W	do	3 a, 8	Feb. 9	29.96	NW	NW, 9	NW	NW, 10	
Sagaporack, Am. S.S.	Norway	Newport News.	58 28 N	19 17 W	do	Noon, 8	do	28.88	SW	SW, 8	SW	—, 10	SW-WSW.
Santa Marta, Am. S. S.	Canal Zone	New York	33 11 N	74 30 W	Feb. 9	4 a, 10	Feb. 10	29.66	WNW	WNW, 9	NW	—, 9	W-WNW-NW
Boston City, Br. S. S.	New York	Cardiff	51 22 N	3 20 W	Feb. 10	8 p, 12	Feb. 15	29.65	W	NW, 5	NW	WNW, 10	Steady.
United States, Dan. S. S.	Oslo	Halifax	58 08 N	16 30 W	Feb. 14	2 p, 15	Feb. 16	29.38	SSW	NW, 9	N	WNW, 10	SW-W-NW.
Carplaka, Am. S. S.	Gotbenburg	Portland, Me.	58 38 N	6 53 W	Feb. 15	4 a, 16	Feb. 17	28.97	W	W, 5	N	N, 10	W-N.
Asia, Dan. M. S.	St. Thomas	Hamburg	33 40 N	41 30 W	Feb. 17	Noon, 17	Feb. 20	30.02	SSE	SSE, 8	S	SSE, 11	S-SSE-SSW.
Carplaka, Am. S. S.	Gotbenburg	Portland, Me.	57 19 N	26 30 W	Feb. 18	8 p, 19	do	29.25	W	W, 10	W	W, 10	W-NW.
Liberty, Am. S. S.	Havre	New York	36 14 N	61 58 W	Feb. 21	Mdt, 21	Feb. 23	28.95	WNW	WNW, 4	NW	NW, 12	Steady.
Exmouth, Am. S. S.	Gibraltar	do	36 10 N	53 00 W	do	5 p, 22	Feb. 24	29.04	S	WSW, 11	WNW	—, 11	S-SW.
West Hika, Am. S. S.	Hamburg	Gulfport	30 58 N	62 55 W	do	Noon, 26	Feb. 27	29.17	W	W, 8	NNW	NW, 11	
Cabo Espartel, Span. S. S.	Seville	New York	35 20 N	51 30 W	Feb. 27	1 a, 27	Mar. 1	28.89	WSW	WSW, 6	WNW	NW, 10	
Singkeep, Du. S. S.	Orau	Boston	37 04 N	44 00 W	Feb. 26.	7 p, 27	Feb. 28	29.05	SSE	SW, 10	W	—, 11	SW-W.
Wyneric, Br. S. S.	Curacao	Liverpool	38 27 N	40 35 W	do	3 a, 28	do	29.45	SE	SSW, 10	WSW	SE, 11	SSE-S-SW.
President Harrison, Am. S. S.	Gibraltar	New York	42 55 N	50 15 W	Feb. 28	1 a, 28	Mar. 2	28.83	WNW	WNW, 8	NW	NW, 12	
NORTH PACIFIC OCEAN													
Michigan, Am. S. S.	Shanghai	San Francisco	48 00 N	171 15 E	Jan. 31	Noon, 31	Feb. 1	28.03	ENE	SSW, 5	W	WSW, 9	SSE-S-SSW.
Arizona Maru, Jap. S. S.	Seattle	Yokohama	52 07 N	154 42 W	Feb. 1	4 a, 2	Feb. 2	29.17	SSW	SSW, 9	SW	SSW, 9	SSW-S-SW.
Hakutatsu Maru, Jap. S. S.	Miike	San Pedro	45 25 N	158 20 E	do	5 a, 3	Feb. 4	29.22	S	SE, 8	SW	NW, 11	SE-SW.
Do	do	do	48 53 N	176 15 W	Feb. 7	10 a, 7	Feb. 8	28.82	SSE	SSW, 8	SW	WSW, 11	SSW-SW.
Laurel, Swed. M. S.	Port Adelaide	San Francisco	31 37 N	131 50 W	Feb. 1	—, 3	Feb. 6	29.74	N	N, 10	NNW	N, 11	N-NNW.
William Penn, Am. M. S.	Iloilo	San Pedro	33 59 N	153 20 W	Feb. 2	3 p, 2	Feb. 2	29.66	SSE	SSE, 10	S	S, 10	SSE-S.
San Diego Maru, Jap. M. S.	Kudamatsu	Los Angeles	37 10 N	157 05 E	do	4 p. 2	do	29.40	E	E, 9	E	E, 9	SSE-E.
San Luis Maru, Jap. M. S.	Elwood	Kudamatsu	30 02 N	179 50 W	do	8 p, 2	Feb. 3	29.31	S	SW, 7	WNW	W, 9	S-SW-W.
Bessemer City, Am. S.S.	Mobile	Los Angeles	14 04 N	96 15 W	Feb. 3	4 p, 4	Feb. 4	29.95	N	ENE, 9	ENE	N, 11	NE-ENE.
Ryujin Maru, Jap. S. S.	Vancouver	Shanghai	53 05 N	157 15 W	Feb. 2	2 a, 2	Feb. 2	28.86	S	SSW, 9	SW	SSW, 9	S-SW.
Do	do	do	50 28 N	174 55 E	Feb. 8	11 a, 8	Feb. 8	28.82	NE	NNW, 9	NW	NNW, 9	NE-WNW.
Ryoyo Maru, Jap. M. S.	Yokohama	San Francisco	47 25 N	152 10 W	Feb. 4	4 a, 5	Feb. 5	29.11	ESE	ESE	SSW	S, 9	
Kinai Maru, Jap. M. S.	do	Los Angeles	43 40 N	164 00 W	Feb. 7	8 a, 9	Feb. 9	28.97	NE	W, 9	W	W, 9	NW-W.
Pres. Wilson, Am. S. S.	Honolulu	Kobe	30 34 N	143 45 E	Feb. 10	5 p, 10	Feb. 10	29.69	SW	SW, 9	NW	SW, 9	SW-W-NW.
Havana Maru, Jap. S. S.	Otaru	San Francisco	49 11 N	171 35 W	Feb. 12	10 p, 12	Feb. 14	28.44	SE	SSW, 9	WSW	SW, 10	S-SSW-SW.
Forresbank, Br. M. S.	San Pedro	Yokohama	32 43 N	176 18 W	Feb. 15	11 a, 16	Feb. 16	29.74	SSW	SW, 8	WNW	SW, 9	WSW-SW-W.
Mojave, Am. S. S.	Yokohama	San Pedro	39 32 N	174 30 E	Feb. 16	1 a, 18	Feb. 19	29.21	NW	S, 10	W	S, 10	4 points.
Tyndareus, Br. S. S.	do	Victoria	49 40 N	163 55 W	Feb. 17	10 a, 18	Feb. 20	28.07	SE	WSW, 9	W	SW, 9	S-WSW-W.
Forresbank, Br. M. S.	San Pedro	Yokohama	32 23 N	165 51 E	Feb. 18	2 p, 19	Feb. 19	29.59	SW	SW, 8	W	WSW, 9	SW-WSW.
Hakusbika Maru, Jap. S. S.	Mobile	Coos Bay	31 54 N	119 28 W	Feb. 19	Mdt, 20	Feb. 21	29.98	NW	WNW, 9	NNW	WNW, 9	Steady.
Do	do	do	38 50 N	124 40 W	Feb. 23	2 p, 23	Feb. 24	30.03	NNW	NNW	N	NNW, 9	Do.
Fukuyo Maru, Jap. S. S.	Japan	Vancouver	48 37 N	178 03 E	Feb. 22	5 a, 23	do	29.49	ESE	NW, 3	W	W, 11	
Batoe, Du. S. S.	Soerabaia	Portland	43 23 N	156 20 W	Feb. 24	8 p, 24	Feb. 25	29.66	S	SW, 8	WNW	W, 10	S-SW-WNW.
Golden Sun, Am. S. S.	Otaru	San Francisco	45 17 N	168 55 E	Feb. 25	8 p, 25	Feb. 27	29.34	ESE	SSE, 7	N	SE, 10	SE-W.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—Over the eastern half of the North Pacific Ocean, except the southeastern part, particularly along the California coast, atmospheric pressure rose in February, following the extraordinarily low barometer covering the upper waters during January, although still below the normal from Juneau westward into the Aleutians. The Aleutian cyclone, central in January near Dutch Harbor, fluctuated to the eastward in February, with an average near-central pressure of 29.23 inches at Kodiak. In this general region the cyclonic activity was greatest and the pressure lowest during the early half of the month.

The North Pacific anticyclone was especially well developed in midocean throughout February. Between California and the Hawaiian Islands cyclonic disturbances related to the northern LOW system prevailed during the first 14 days, but thereafter the anticyclone remained unbroken to the coast by intruding depressions. In Asiatic waters conditions were less stable, several HIGH and LOWS succeeding each other, coming from the continent.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, February, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Date	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.08	−0.04	30.56	7th	29.74	1st.
Dutch Harbor [1]	29.36	−0.24	30.20	22d	28.48	14th.
St. Paul [1]	29.48	−0.17	29.98	22d	28.76	9th.
Kodiak [1]	29.23	−0.39	29.78	23d	28.44	11th.
Midway Island [1]	30.10	+0.11	30.28	24th	29.76	1st.
Honolulu [3]	30.13	+0.03	30.23	14th	29.99	2d.
Juneau [3]	29.69	−0.23	30.29	2d	29.10	18th.
Tatoosh Island [3] [4]	30.00	+0.02	30.48	23d	29.37	16th.
San Francisco [3] [4]	30.01	−0.06	30.27	18th	29.56	12th.
San Diego [3] [4]	29.96	−0.08	30.22	18th	29.56	12th.

[1] P. m. observations only.
[2] For 27 days.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

Cyclones and gales.—Conditions of wind and weather on the Pacific were far less intense than in January, and general storm activity was less widespread. Of the traveling cyclones from Asiatic waters, none was of great importance. A moderatly deep storm caused a northwesterly gale of force 11 southeast of the Kurils on the 3d, and fresh to strong gales were noted on a few days east of Japan in connection with some rather shallow and brief-lived disturbances.

In upper waters south and southeast of the Aleutians gales of force 8 to 10 occurred on about 20 days, irregularly distributed, and many of them purely local in character. They were most frequent along that part of the northern routes lying southwest of the Gulf of Alaska, in the region most frequented this month by the Aleutian disturbance. However, the heaviest winds, westerly gales of force 11, in northern waters occurred south of the central Aleutians, one on the 8th, at which time the cyclone was of considerable depth, and the other on the 23d, with the barometer only moderately depressed.

During the early half of February two cyclones, separated from the lower extensions of the Aleutian cyclone, developed, though to no great depth, to the westward of California. The former gathered on the 1st and entered the coast on the 5th. The latter was disconnected from the upper disturbance on the 7th and was reunited with it on the 13th or 14th. Its highest reported winds were of force 8. The earlier was the severer, as may be indicated particularly by the report of the Swedish motor ship *Laurel*, which encountered northerly gales on the 1st, near 25° N., 140° W., and continued in them until near San Francisco on the 6th. On the 3d the maximum wind had increased to a whole gale, and on the 4th, near 32° N., 132° W., to force 11, thus showing the cyclone to have been rather intense, at least in some localities.

Two severe northers were experienced in the Gulf of Tehuantepec. One on the 4th developed full storm force. During the afternoon of the 25th, and continuing through the night, the motor ship *William Penn*, entering the gulf, encountered fresh to whole northerly gales, with squalls of hurricane force and such "short, vicious seas," that at times she "was literally under water."

The prevailing wind direction at Honolulu was from the east, with a maximum velocity of 29 miles an hour from the same direction on the 24th.

Fog.—Fog was more scattered and infrequent that it had been before for many months. At the most, it was reported at some distance off the California coast on four days, and off the coast of Washington and in the vicinity of Midway Island on three days.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the mean temperature for the Caribbean Sea and the Straits of Florida for February of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the February, 1930, means from the 11-year means for February (1920–1930), and the changes from the temperatures for the preceding month of January, 1930.

The means for 1919 are not used in the computations for comparisons, the poor distribution and the dearth of data for that year making them somewhat unreliable.

The chart shows the number of observations taken during the month of February, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

TABLE 1.—*Lengths of "Quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[1] In three cases, indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for February, 1919–1930*

Year	Caribbean Sea: Number of observations	Caribbean Sea: Mean temperature	Straits of Florida: Number of observations	Straits of Florida: Mean temperature
1919 [1]	31	79.4	14	[1]74.8
1920	114	78.6	22	74.2
1921	167	78.0	42	74.6
1922	187	78.4	82	74.6
1923	281	77.3	68	75.4
1924	369	78.5	102	73.6
1925	213	78.1	72	75.0
1926	350	79.2	115	73.2
1927	285	79.0	106	76.1
1928	407	79.0	125	74.0
1929	387	78.8	130	75.1
1930	481	78.4	145	74.6
Mean (1920–1930)		78.5		74.6

[1] Not used in computations because of insufficient data.

TABLE 3.—*Mean sea-surface temperatures (° F.), and number of observations, February, 1930*

Quarter	Period	Caribbean Sea: Number of observations	Caribbean Sea: Mean	Caribbean Sea: Departure from 11-year mean (1920–1930)	Caribbean Sea: Change from preceding month	Straits of Florida: Number of observations	Straits of Florida: Mean	Straits of Florida: Departure from 11-year mean (1920–1930)	Straits of Florida: Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	1 to 7	112	78.8			37	74.8		
II	8 to 14	93	78.1			32	74.0		
III	15 to 21	126	78.4			37	75.3		
IV	22 to 28	150	78.5			39	74.5		
Month		481	78.4	−0.1	−0.3	145	74.6	0.0	−1.0

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, February, 1931

(For description of tables and charts, see REVIEW, January, p. 50)

Section	Temperature: Section average	Temperature: Departure from the normal	Monthly extremes: Station	Highest	Date	Station	Lowest	Date	Precipitation: Section average	Precipitation: Departure from the normal	Greatest monthly: Station	Amount	Least monthly: Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	49.8	+1.2	2 stations	77	[1]7	2 stations	18	[1]10	3.41	−1.90	River Falls	5.42	Birmingham	1.68
Arizona	48.6	+0.8	Gila Bend	86	[1]1	Alpine	−1	17	3.75	+2.58	Natural Bridge	8.19	Springerville	0.52
Arkansas	48.2	+4.9	Hope	75	[1]3	Dutton	14	10	4.77	+1.47	Dutton	8.04	Junction	2.50
California	48.9	+1.7	Blythe	84	3	Twin Lakes	−10	16	2.56	−1.88	Mount Wilson	8.82	Bishop Creek	0.21
Colorado	32.5	+4.8	2 stations	70	[1]3	2 stations	−16	17	1.26	+0.26	La Veta Pass	6.15	Gunnison	0.00
Florida	58.9	−1.4	Belle Glade	84	18	do	24	11	2.11	−1.00	Apalachicola	5.75	Palatka	0.40
Georgia	49.8	+1.3	Waycross	79	18	Clayton	13	11	2.83	−2.15	Cornelia	4.47	Meldrim	1.43
Idaho	28.3	+0.2	Glenns Ferry	74	15	Felt	−18	[1]8	1.09	−0.69	Roland	4.30	Grand View	T.
Illinois	37.9	+8.5	Carbondale	72	7	Marengo	1	10	1.29	−0.64	Cairo	3.38	Geneseo	0.12
Indiana	37.6	+7.4	Rome	68	7	Plymouth	10	10	1.65	−0.87	Rome	3.31	Whiting	0.24
Iowa	35.4	+12.8	3 stations	65	[1]2	2 stations	−4	10	0.25	−0.96	Keokuk (No. 2)	1.13	14 stations	T.
Kansas	41.7	+7.9	Atwood	76	19	Centralia	6	10	0.98	−0.03	Overbrook (near)	2.88	Coldwater	0.13
Kentucky	41.6	+5.0	2 stations	72	7	Beattyville	12	15	3.20	−0.25	Franklin	5.49	Whitesburg	1.51
Louisiana	55.8	+2.3	Morgan City	80	7	2 stations	20	11	3.73	−0.84	Logansport	6.36	Tallulah	2.12
Maryland-Delaware	36.6	+2.6	Princess Anne, Md	65	9	Oakland, Md	7	13	1.66	−1.42	Sines, Md	3.31	Great Falls, Md	1.21
Michigan	28.9	+8.9	Morenci	61	28	3 stations	−21	10	0.79	−0.90	Houghton	2.23	Secord	0.12
Minnesota	27.4	+15.4	2 stations	63	24	2 stations	−26	[1]12	0.40	−0.32	Little Falls	1.85	Redby	T.
Mississippi	51.8	+2.6	Port Gibson	78	8	do	19	11	3.65	−1.21	Clarksdale	7.07	Brookhaven	2.22
Missouri	40.9	+8.5	Doniphan	75	3	do	5	10	2.40	+0.29	Campbell	5.07	Lucerne	0.50
Montana	31.7	+10.5	Ballantine	64	2	Hebgen Dam	−20	8	0.36	−0.36	Heron	3.25	3 stations	0.00
Nebraska	36.7	+11.1	McCook	74	19	2 stations	3	[1]9	0.64	−0.08	Orleans	2.10	2 stations	T.
Nevada	37.9	+2.8	Logandale	76	28	Owyhee	−4	22	0.73	−0.25	Las Vegas	2.71	Beowawe	0.07
New England	24.0	+1.4	Bridgeport, Conn	56	28	Van Buren, Me	−32	2	2.14	−1.05	Rockport, Mass	4.96	Bethlehem, N. H	0.42
New Jersey	33.3	+3.9	Flemington	62	28	Sussex	−9	11	2.18	−1.45	Chatham	3.42	Cape May City	0.81
New Mexico	38.5	+1.1	Artesia	74	5	Elizabethtown	−13	23	1.49	+0.83	Cloverdale	5.80	Gallegos (near)	0.07
New York	25.1	+3.0	Flushing	58	28	Indian Lake	−28	3	1.80	−0.99	High Market	3.37	Lockport	0.67
North Carolina	44.1	+1.5	Nashville	78	[1]8	Mount Mitchell	4	15	1.83	−2.29	Rock House	5.00	2 stations	0.70
North Dakota	28.0	+17.8	Berthold Agency	62	19	Towner	−31	9	0.28	−0.21	Fullerton	1.62	5 stations	0.00
Ohio	35.2	+5.7	5 stations	65	28	Canfield	4	11	1.85	−0.50	Gallipolis	3.24	Wauseon	1.17
Oklahoma	47.8	+6.5	Eufaula	79	2	Bartlesville	16	10	2.44	+1.27	Tuskahoma	7.51	Boise City	0.50
Oregon	36.5	+0.7	Marshfield	72	12	Seneca	−5	7	1.71	−1.36	Valsetz	9.75	Umatilla	0.02
Pennsylvania	31.9	+3.8	3 stations	66	28	Hawley	−16	11	1.98	−0.99	Elk Lick	3.61	Erie	0.87
South Carolina	47.7	+0.2	2 stations	77	18	Caesars Head	15	11	1.77	−2.51	Walhalla	4.63	Society Hill	0.53
South Dakota	33.7	+14.1	Gannvalley	69	15	McLaughlin	−14	13	0.32	−0.31	2 stations	0.90	2 stations	T.
Tennessee	44.3	+3.3	Clarksville	73	7	Rugby	10	15	4.08	−0.26	Perryville	8.11	Elizabethton	1.20
Texas	53.4	+2.4	Riogrande	86	22	3 stations	21	[1]9	2.96	+1.17	Bon Wier	8.15	Clint	0.27
Utah	33.1	+2.9	St. George	69	[1]25	Lewiston	−2	1	0.71	−0.57	Silver Lake	1.98	Wendover	0.00
Virginia	40.2	+2.9	Diamond Springs	74	9	Burkes Garden	8	11	1.89	−1.20	Emporia	3.59	Rocky Mount	0.81
Washington	36.9	+1.9	2 stations	68	18	Stockdill Ranch	0	7	3.23	−0.87	Big Four	15.75	Wapato	0.03
West Virginia	35.8	+3.6	do	68	[1]7	Bayard	5	3	2.57	−0.56	Pickens	4.68	Wardensville	1.08
Wisconsin	28.9	+12.2	Downing	62	21	2 stations	−25	10	0.61	−0.57	Wausau	1.30	Cuba	0.16
Wyoming	28.1	+5.6	Torrington	67	19	Riverside	−24	22	0.48	−0.31	Beebler River	2.18	Deaver	0.02
Alaska (January)	12.7	+10.4	Mile Seven (Cordova).	59	[1]21	Eagle	−57	22	2.55	+0.50	Mile Seven (Cordova).	20.36	McKinley Park	0.00
Hawaii	69.4	+0.7	Mabukoma	89	99	Volcano Observatory.	47	[1]2	4.14	−2.25	Wahiawa Water Co. Intake	17.60	6 stations	0.00
Porto Rico	73.7	+0.3	Mayaguez	93	3	Guineo Reservoir	49	20	5.98	+3.06	Toro Negro	16.82	Penuelas	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							27.1	+1.7										74	2.23	−1.0										5.7		
Eastport	76	67	85	29.85	29.94	−0.04	24.2	+2.7	42	14	30	−1	1	18	31	23	18	76	2.25	−1.1	11	7,939	nw.	31	ne.	19	6	4	18	7.4	11.7	0.3
Greenville, Me	1,070	6	----	28.72	29.98	------	18.0	------	42	26	27	−16	3	9	44	----	----	----	1.84	------	12	5,242	n.	22	------	15	10	5	13	----	19.0	----
Portland, Me	103	82	117	29.87	30.00	−.02	26.1	+2.3	47	28	33	3	3	19	28	23	16	67	3.15	−0.8	10	5,509	n.	26	s.	13	11	5	12	5.5	20.9	4.1
Concord	289	70	79	29.66	29.99	−.05	25.1	+2.3	47	26	34	−16	3	16	51	----	----	----	1.29	−1.6	8	3,852	nw.	22	nw.	27	12	6	10	5.0	12.2	3.0
Burlington	403	11	48	29.57	30.04	+.01	18.6	−0.8	41	13	28	−15	3	9	39	----	----	----	1.94	+0.4	14	5,472	s.	33	s.	8	6	7	15	7.0	21.4	19.0
Northfield	876	12	60	29.04	30.04	.00	17.7	+1.3	43	26	30	−22	3	5	55	15	13	85	0.64	−1.6	9	3,810	n.	25	s.	13	6	11	11	6.2	5.5	15.2
Boston	125	106	165	29.84	29.98	−.06	30.6	+1.8	49	13	38	4	1	23	31	27	21	68	4.21	+0.8	9	5,716	nw.	24	nw.	27	10	6	12	5.6	14.0	0.0
Nantucket	12	14	90	29.93	29.94	−.10	33.2	+2.5	49	17	39	10	1	28	27	31	28	82	3.30	−0.1	10	9,267	nw.	37	ne.	20	13	5	10	5.5	5.7	0.0
Block Island	26	11	46	29.94	29.97	−.09	31.7	+1.3	46	14	37	12	1	26	27	29	26	77	2.10	−1.6	10	11,674	w.	48	w.	14	11	6	11	5.4	2.1	0.0
Providence	160	215	251	29.80	29.98	−.07	30.4	+1.4	49	17	38	4	1	23	31	27	21	71	1.98	−1.7	8	7,942	nw.	38	nw.	27	11	4	13	5.3	4.6	T.
Hartford	159	122	----	29.83	30.02	−.04	29.0	+1.8	49	13	37	2	3	21	30	----	----	----	1.65	−2.2	11	------	nw.	----	------	----	12	5	11	5.0	6.1	0.0
New Haven	106	74	153	29.89	30.02	−.05	31.0	+2.0	50	28	38	9	1	24	26	27	22	70	2.04	−2.0	9	6,325	nw.	26	ne.	18	14	6	8	4.5	6.0	0.0
Middle Atlantic States							36.3	+2.9										70	1.76	−1.4										5.3		
Albany	97	107	115	29.94	30.05	−.02	25.8	+1.7	46	28	34	−9	3	17	36	23	17	71	2.07	−0.4	9	4,382	s.	21	sw.	27	11	7	10	5.2	6.1	2.0
Binghamton	871	10	84	29.09	30.05	−.03	25.6	+1.6	48	17	35	−12	3	17	48	----	----	----	1.97	−0.3	11	3,663	nw.	20	sw.	13	7	5	16	7.2	9.2	0.1
New York	314	414	454	29.67	30.03	−.05	34.1	+2.8	55	28	42	12	11	26	32	29	22	64	2.44	−1.4	10	10,844	nw.	45	nw.	14	9	9	10	5.5	3.8	0.0
Bellefonte	1,050	5	36	28.90	30.05	------	30.0	------	54	28	39	−14	11	21	46	26	24	82	1.59	------	9	------	sw.	----	------	----	9	6	13	6.2	8.8	0.0
Harrisburg	374	94	104	29.66	30.08	−.01	35.0	+4.8	55	28	42	15	11	28	29	30	23	63	1.44	−1.5	10	4,140	nw.	25	nw.	14	14	2	12	5.2	2.8	0.0
Philadelphia	114	123	367	29.93	30.06	−.04	37.4	+3.5	55	28	44	18	11	30	25	31	23	60	1.92	−1.4	8	8,843	nw.	34	nw.	14	10	7	11	5.3	1.1	0.0
Reading	325	81	98	29.70	30.06	------	35.4	+6.6	55	28	43	15	11	28	28	30	25	69	1.90	−1.5	9	4,098	n.	23	nw.	14	13	4	11	5.0	1.6	0.0
Scranton	805	111	119	29.16	30.06	−.02	29.4	+2.1	52	28	38	2	3	21	37	26	21	75	1.45	−1.6	10	4,066	n.	22	nw.	14	7	9	12	6.3	11.8	T.
Atlantic City	52	37	172	29.98	30.04	−.07	36.5	+2.9	55	26	44	16	11	29	27	32	27	72	1.12	−2.2	7	9,945	nw.	40	se.	17	12	7	9	4.8	T.	0.0
Cape May	17	13	49	------	------	------	36.4	+2.3	52	26	44	19	3	29	22	33	30	82	0.81	−2.5	7	------	nw.	----	------	----	11	5	12	----	T.	0.0
Sandy Hook	22	10	55	29.99	30.01	------	34.2	------	52	28	40	16	11	28	29	30	26	76	1.85	−1.9	9	10,068	nw.	40	nw.	14	13	7	8	4.5	3.7	0.0
Trenton	190	159	183	29.83	30.04	------	34.4	+3.7	55	28	43	13	11	26	28	30	23	67	2.08	−1.2	7	6,741	n.	32	nw.	14	12	5	11	5.2	1.1	0.0
Baltimore	123	100	215	29.92	30.05	−.06	39.6	+4.2	58	13	47	21	3	32	30	33	26	63	1.41	−2.0	9	6,088	nw.	30	nw.	14	11	5	12	5.2	0.7	0.0
Washington	112	62	85	29.94	30.07	−.04	39.4	+4.1	60	28	47	21	11	31	31	33	25	61	1.36	−1.9	8	4,016	nw.	25	nw.	14	12	4	12	5.3	T.	0.0
Cape Henry	18	8	54	30.03	30.05	------	41.4	+0.2	72	9	49	27	15	34	36	37	32	75	2.32	−0.9	8	7,302	n.	40	n.	14	11	7	10	5.0	T.	0.0
Lynchburg	681	153	188	29.31	30.07	−.04	42.0	+1.7	62	26	53	22	15	31	34	36	30	67	1.81	−1.3	9	3,909	w.	27	n.	14	10	9	9	4.7	0.0	0.0
Norfolk	91	170	205	29.97	30.07	−.04	43.8	+1.1	69	9	52	24	15	36	34	37	30	67	1.70	−1.5	8	7,188	n.	36	sw.	9	10	7	11	5.1	T.	0.0
Richmond	144	11	52	29.92	30.08	−.03	41.5	+1.9	63	4	52	20	15	31	36	35	30	73	2.60	−0.6	8	4,203	ne.	29	w.	13	12	7	9	4.8	T.	0.0
Wytheville	2,304	49	55	27.63	30.07	−.05	38.8	+3.7	58	24	49	15	15	29	30	32	27	70	1.48	−1.5	9	3,569	w.	19	w.	12	9	8	11	5.4	1.9	0.0
South Atlantic States							49.0	+1.1										70	1.90	−1.8										4.9		
Asheville	2,253	89	104	27.68	30.10	−.03	41.7	+3.2	63	22	53	17	15	30	38	34	29	70	1.24	−1.9	9	4,733	nw.	28	nw.	9	10	9	9	5.2	T.	0.0
Charlotte	779	55	62	29.22	30.07	−.05	46.2	+2.3	67	18	56	24	15	36	32	39	31	62	1.93	−2.2	8	3,248	ne.	16	nw.	14	12	4	12	5.1	T.	0.0
Greensboro	886	5	56	29.10	30.08	------	41.5	------	63	18	54	20	15	29	40	35	30	75	1.77	------	7	4,355	sw.	27	sw.	13	9	11	8	5.1	0.0	0.0
Hatteras	11	5	50	30.04	30.05	−.06	46.9	−0.5	71	9	54	31	15	40	30	43	39	77	2.34	−1.7	8	8,606	ne.	37	n.	14	11	11	6	4.2	T.	0.0
Raleigh	376	103	146	29.66	30.07	−.04	46.0	+2.8	70	18	57	23	15	35	31	38	31	63	1.80	−2.1	7	5,016	sw.	28	sw.	9	10	11	7	4.9	0.0	0.0
Wilmington	78	81	91	30.00	30.09	−.03	49.4	+1.5	73	18	60	26	15	39	32	42	38	73	1.72	−1.5	7	3,921	n.	24	n.	10	9	13	6	4.5	0.0	0.0
Charleston	48	11	92	30.02	30.07	−.05	51.8	−0.6	74	18	60	32	15	43	25	46	41	74	1.67	−1.3	6	5,812	sw.	31	n.	14	10	6	12	5.4	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.08	−.03	49.4	+1.2	70	8	60	28	11	38	34	42	36	65	1.25	−2.5	9	3,877	ne.	27	sw.	9	14	4	10	4.6	0.0	0.0
Due West	711	10	55	29.31	30.10	------	46.4	------	66	6	57	24	15	35	37	----	----	----	1.98	------	8	4,837	sw.	25	w.	9	9	6	9	4.6	0.0	0.0
Greenville, S. C	1,039	139	146	28.94	30.05	------	46.8	+3.5	66	18	56	26	11	38	29	40	33	64	3.80	−1.4	8	4,977	ne.	29	n.	14	13	5	10	4.7	T.	0.0
Augusta	182	62	77	29.86	30.06	−.06	49.8	−0.1	71	17	62	30	15	38	37	44	42	81	1.87	−2.2	9	2,628	nw.	17	w.	9	12	7	9	4.5	0.0	0.0
Savannah	65	150	194	29.98	30.06	−.06	54.7	+0.7	75	18	64	33	11	45	28	46	41	70	1.82	−1.3	6	6,600	s.	35	nw.	20	11	7	10	5.1	0.0	0.0
Jacksonville	43	209	245	30.01	30.06	−.06	56.4	−1.6	74	17	64	34	11	49	22	49	44	69	1.49	−1.5	7	6,290	n.	33	nw.	20	10	6	12	5.4	0.0	0.0
Florida Peninsula							64.7	−1.8										77	2.55	+0.7										5.6		
Key West	22	10	64	30.00	30.02	−.05	67.5	−3.0	81	28	73	55	11	62	15	62	59	80	3.89	+2.6	6	6,817	n.	28	nw.	4	9	14	5	4.8	0.0	0.0
Miami	25	124	168	30.01	30.04	−.07	65.5	−1.6	78	14	72	47	5	59	25	59	55	74	2.12	+0.3	9	6,749	se.	34	s.	17	3	10	15	7.0	0.0	0.0
Tampa	35	79	197	30.01	30.05	−.05	61.0	−0.9	77	13	70	39	11	52	25	54	50	76	1.65	−0.9	7	6,807	nw.	46	s.	17	11	5	12	5.4	0.0	0.0
Titusville	44	5	----	30.02	30.07	------	59.5	------	78	17	69	39	11	50	33	----	----	----	0.87	------	6	------	nw.	----	------	----	10	13	5	5.2	0.0	0.0
East Gulf States							52.4	+1.1										71	2.92	−1.9										4.6		
Atlanta	1,173	190	216	28.80	30.06	−.06	47.6	+2.3	67	6	56	25	11	39	30	41	33	64	2.40	−2.4	10	5,458	nw.	33	nw.	9	13	4	11	4.9	0.0	0.0
Macon	370	78	87	29.67	30.07	−.05	49.8	+0.5	72	17	62	25	11	38	39	42	36	67	2.23	−2.2	9	3,333	nw.	20	nw.	9	13	6	9	4.5	0.0	0.0
Thomasville	273	49	103	29.76	30.07	−.05	54.6	−0.4	75	17	65	30	11	44	30	46	41	72	2.68	−1.8	7	4,529	nw.	24	nw.	14	9	9	10	5.4	0.0	0.0
Apalachicola	36	11	51	30.02	30.06	------	55.3	------	72	17	62	34	11	48	23	51	48	82	5.75	+1.8	7	5,280	n.	29	se.	16	12	5	11	4.7	0.0	0.0
Pensacola	56	149	185	30.01	30.07	−.04	54.9	−0.3	68	4	61	34	15	48	22	50	47	79	2.75	−1.6	8	7,631	n.	29	se.	16	12	7	9	4.4	0.0	0.0
Anniston	741	9	57	29.29	30.10	−.02	47.6	+1.8	69	6	59	20	11	36	36	----	----	----	2.81	−2.6	8	2,916	nw.	17	nw.	9	13	4	11	4.7	0.0	0.0
Birmingham	700	11	48	29.30	30.08	−.04	49.7	+1.7	69	6	60	24	11	40	32	42	36	68	1.68	−3.4	11	4,177	n.	24	se.	16	13	4	11	4.7	0.0	0.0
Mobile	57	125	161	30.00	30.06	−.05	55.4	+0.7	74	28	64	33	11	46	27	49	45	76	2.71	−2.6	9	5,711	n.	28	n.	14	13	9	6	4.2	0.0	0.0
Montgomery	223	100	112	29.83	30.08	−.04	52.6	+1.0	74	7	62	28	11	43	31	45	38	64	3.35	−2.1	8	3,608	n.	24	n.	14	14	5	9	4.4	0.0	0.0
Corinth	469	6	----	------	------	------	48.0	------	75	6	59	22	11	37	39	----	----	----	3.28	------	8	------	nw.	----	------	----	8	10	10	----	0.0	0.0
Meridian	375	87	95	29.67	30.07	−.04	51.0	+1.4	73	7	62	24	11	40	36	44	39	72	2.47	−3.0	8	3,341	n.	23	sw.	13	14	3	11	4.5	0.0	0.0
Vicksburg	247	65	73	29.80	30.09	−.01	53.8	+2.0	73	7	63	31	11	44	27	46	39	65	2.48	−2.3	9	4,255	n.	21	se.	22	14	6	8	4.4	0.0	0.0
New Orleans	53	76	84	30.00	30.06	−.03	59.0	+1.7	78	17	67	37	11	51	24	53	48	74	3.79	−0.5	7	4,111	ne.	18	n.	14	13	7	8	4.2	0.0	0.0
West Gulf States							55.2	+3.7										77	3.80	+1.3										5.6		
Shreveport	249	77	93	29.79	30.06	−.03	53.8	+2.9	72	4	62	34	15	45	26	49	46	79	3.32	0.0	12	3,516	se.	16	nw.	13	12	6	10	5.1	0.0	0.0
Bentonville	1,303	11	44	28.67	30.06	−.04	45.4	+6.9	66	2	55	20	10	36	31	----	----	----	3.52	------	12	3,275	s.	19	s.	6	16	2	10	----	0.0	0.0
Fort Smith	457	79	94	29.56	30.05	−.05	49.1	+6.3	70	5	57	28	10	41	31	44	39	75	5.97	+3.4	9	4,401	e.	20	e.	21	11	4	13	5.6	0.0	0.0
Little Rock	357	136	153	29.69	30.08	−.03	49.6	+4.7	69	3	58	29	15	41	27	43	37	66	4.03	+0.2	9	4,969	n.	31	n.	8	14	1	13	5.1	0.0	0.0
Austin	605	136	148	29.39	30.03	------	56.8	+3.4	76	19	66	36	10	48	35	51	48	77	5.63	+3.3	12	4,985	se.	28	n.	13	8	10	10	5.6	0.0	0.0
Brownsville	57	83	100	29.96	30.02	------	63.7	+1.1	79	8	70	50	4	57	25	59	57	85	0.81	−0.4	7	5,819	se.	26	se.	21	3	12	13	7.2	0.0	0.0
Corpus Christi	20	11	78	30.01	30.03	−.02	61.6	+3.2	80	28	68	48	14	55	30	57	55	81	1.74	+0.3	5	6,309	se.	34	nw.	15	6	8	14	6.4	0.0	0.0
Dallas	512	220	227	29.49	30.05	------	52.1	------	70	20	60	33	14	44	29	----	----	----	2.36	+0.1	12	7,015	se.	43	sw.	22	14	5	9	4.2	0.0	0.0
Fort Worth	670	106	114	29.31	30.03	−.04	53.6	+5.3	72	20	62	34	14	46	30	48	44	74	2.84	+1.1	13	4,546	se.	30	se.	21	8	7	13	6.0	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.01	58.8	+2.5	73	17	64	45	15	54	17	55	52	84	4.23	+1.4	7	6,439	se.	27	n.	9	11	4	13	5.6	0.0	0.0
Groesbeck	461	11	56	29.55	30.04	------	53.9	------	72	20	62	36	10	46	28	----	----	----	5.06	+2.2	10	6,276	n.	27	se.	15	8	8	12	6.0	0.0	0.0
Houston	138	292	314	29.91	30.06	------	58.4	+2.5	74	20	66	40	10	51	23	----	----	----	4.76	+1.6	10	7,557	se.	44	e.	16	10	5	13	5.9	0.0	0.0
Palestine	510	64	72	29.52	30.06	−.02	54.4	+3.2	72	20	63	38	10	46	27	49	45	76	4.69	+1.6	10	4,644	s.	21	nw.	22	10	5	13	5.5	0.0	0.0
Port Arthur	34	58	66	30.02	30.06	------	58.4	------	76	17	65	39	10	51	22	----	----	----	4.96	+1.4	7	4,685	n.	28	e.	16	10	4	14	5.9	0.0	0.0
San Antonio	693	242	301	29.29	30.02	−.03	57.4	+2.0	75	17	66	40	10	49	28	52	47	73	2.68	+1.0	9	7,240	n.	36	ne.	15	10	10	8	5.3	0.0	0.0
Taylor	571	38	51	29.46	30.06	.00	55.6	+4.3	74	19	65	35	10	47	34	----	----	----	3.87	+1.8	10	4,887	s.	24	se.	15	9	10	9	5.2	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							40.3	+4.3										73	2.78	−0.6										6.1		
Chattanooga	762	190	215	29.25	30.07	−0.06	47.0	+2.9	66	8	56	25	15	38	30	40	33	63	4.78	−0.1	9	4,017	ne.	24	w.	9	12	4	12	5.1	0.0	0.0
Knoxville	995	102	111	29.00	30.08	−.04	44.7	+2.8	66	8	54	21	15	35	31	39	33	70	2.93	−1.6	12	3,200	n.	20	sw.	7	9	4	15	5.7	T.	0.0
Memphis	399	76	97	29.64	30.07	−.04	48.3	+4.0	68	6	56	28	15	40	27	42	37	69	4.85	+0.5	8	5,141	n.	28	n.	8	14	3	11	4.8	0.0	0.0
Nashville	546	168	191	29.51	30.11	−.01	44.3	+2.7	67	6	53	22	15	36	32	39	34	72	5.05	+0.9	10	4,977	nw.	26	nw.	13	11	2	15	5.8	T.	0.0
Lexington	989	193	230	29.03	30.13	+.02	39.3	+3.9	62	7	47	18	15	32	26	----	----	----	3.40	−0.2	9	6,946	n.	30	w.	13	8	4	16	6.2	1.5	0.0
Louisville	525	188	234	29.52	30.11	.00	41.4	+4.2	63	7	49	20	14	34	27	37	32	73	2.88	−0.7	7	5,535	n.	24	n.	13	7	7	14	6.4	1.0	0.0
Evansville	431	76	116	29.63	30.11	.00	41.9	+5.6	66	7	50	19	14	34	28	37	31	71	2.33	−0.9	10	4,879	n.	23	sw.	12	10	5	13	5.6	T.	0.0
Indianapolis	822	194	230	29.18	30.09	−.01	38.0	+6.9	60	3	45	14	14	31	27	34	29	73	1.76	−1.0	9	5,869	sw.	26	sw.	3	10	5	13	5.8	T.	0.0
Royal Center	736	11	55	29.28	30.11	-----	35.2	-----	57	3	43	14	14	28	30	----	----	----	1.11	−1.2	10	5,573	nw.	26	nw.	13	6	10	12	6.0	0.5	0.0
Terre Haute	575	96	129	29.47	30.10	-----	38.9	-----	63	3	46	14	14	31	29	35	31	78	2.06	−0.6	11	4,721	nw.	23	n.	3	9	5	14	5.7	0.1	0.0
Cincinnati	627	11	51	29.41	30.11	+.01	38.8	+6.0	63	7	46	19	14	31	30	34	31	77	1.88	−1.1	10	3,824	sw.	19	sw.	7	10	4	14	6.4	1.3	0.0
Columbus	822	216	230	29.19	30.09	.00	36.8	+6.1	60	28	44	16	14	30	27	33	28	73	1.54	−1.1	13	5,686	nw.	28	nw.	13	6	8	14	6.2	1.9	0.0
Dayton	899	137	173	29.12	30.10	-----	37.6	+6.2	60	28	44	18	14	31	26	34	30	76	1.77	−0.9	14	4,475	sw.	25	w.	7	6	9	13	6.2	0.4	0.0
Elkins	1,947	59	67	28.00	30.13	+.03	34.2	+2.6	61	28	43	15	11	25	40	30	27	81	3.19	+0.1	13	2,696	nw.	22	nw.	13	6	5	17	7.2	3.7	0.0
Parkersburg	637	77	82	29.44	30.12	+.02	37.8	+3.6	64	28	46	14	11	29	35	33	28	75	2.97	−0.2	11	2,951	nw.	17	nw.	14	8	3	17	6.9	3.0	0.0
Pittsburgh	842	353	410	29.15	30.09	.00	34.6	+2.3	62	28	42	15	14	28	32	31	27	77	1.93	−0.7	11	5,304	sw.	27	nw.	14	6	7	15	6.9	4.1	0.0
Lower Lake Region							29.3	+4.4										79	1.37	−1.0										7.0		
Buffalo	767	247	280	29.19	30.05	−.01	27.1	+2.8	50	28	34	6	1	20	29	25	23	85	1.50	−1.4	12	9,469	sw.	50	w.	15	3	9	16	7.4	10.2	0.3
Canton	448	10	61	29.53	30.04	-----	17.9	−0.1	39	13	29	−19	7	7	49	----	----	----	1.15	−1.1	17	5,773	sw.	25	sw.	13	9	7	12	6.2	10.5	13.0
Ithaca	836	74	100	29.11	30.05	-----	27.2	+2.7	47	17	35	−1	3	19	34	24	20	80	1.34	−0.6	16	5,859	nw.	27	nw.	14	4	6	18	7.7	14.2	0.4
Oswego	335	71	85	29.67	30.05	−.01	25.8	+1.9	42	17	34	−7	3	18	45	24	21	81	1.67	−1.0	16	6,245	s.	26	n.	2	3	2	23	8.3	13.9	7.7
Rochester	523	86	102	29.47	30.07	+.01	28.2	+3.6	44	28	36	4	3	21	38	26	22	77	1.40	−1.3	15	5,356	sw.	28	w.	14	3	10	15	7.4	6.8	0.8
Syracuse	596	65	79	29.38	30.05	−.02	27.2	+3.4	45	13	35	−5	3	20	44	----	----	----	1.27	−1.4	18	4,470	w.	22	sw.	14	4	5	19	7.6	7.7	1.6
Erie	714	130	166	29.27	30.06	−.01	30.4	+3.5	52	28	37	12	11	24	30	28	25	80	0.87	−1.7	7	6,964	nw.	32	sw.	2	6	6	16	7.1	1.6	0.0
Cleveland	762	267	337	29.23	30.07	.00	33.0	+5.6	58	28	39	13	14	27	31	29	25	76	1.29	−1.2	6	7,647	n.	37	w.	13	6	6	16	7.0	0.5	0.0
Sandusky	629	5	67	29.39	30.09	+.02	33.4	+6.0	53	3	39	16	14	28	28	----	----	----	1.71	−0.4	9	4,891	sw.	27	w.	13	7	4	17	6.8	1.4	0.0
Toledo	628	208	243	29.39	30.10	+.03	34.0	+6.7	59	28	40	14	14	28	29	30	25	73	1.46	−0.6	10	7,000	sw.	30	w.	15	11	5	12	5.7	0.8	0.0
Fort Wayne	856	100	119	29.14	30.09	-----	34.6	+8.8	59	28	41	16	14	28	30	31	28	79	1.36	−1.0	12	5,416	nw.	25	nw.	13	6	9	13	6.2	2.2	0.0
Detroit	730	218	258	29.27	30.09	+.03	32.8	+7.5	56	28	39	12	14	27	26	30	26	80	1.40	−0.8	8	6,101	n.	25	sw.	5	10	4	14	6.0	3.5	0.0
Upper Lake Region							28.9	+9.6										82	1.00	−0.8										6.5		
Alpena	609	13	92	29.39	30.08	+.05	26.0	+8.0	44	15	33	1	14	20	27	24	21	81	0.88	−0.8	11	6,333	nw.	29	e.	7	6	5	17	7.1	8.2	T.
Escanaba	612	54	60	29.40	30.09	+.03	26.4	+11.0	45	3	33	6	10	20	24	24	21	83	0.86	−0.6	4	5,710	n.	30	n.	9	8	6	14	6.1	8.6	5.0
Grand Haven	632	54	89	29.38	30.08	+.03	31.6	+7.4	47	27	38	10	10	26	22	30	27	85	0.86	−1.3	10	6,405	sw.	31	n.	3	5	6	17	7.0	5.6	0.0
Grand Rapids	707	70	244	29.30	30.10	+.05	32.2	+8.5	50	25	39	8	10	26	25	29	25	77	0.79	−1.4	10	6,949	sw.	33	sw.	1	7	6	15	6.5	7.2	0.0
Houghton	668	64	99	29.33	30.09	+.04	24.7	+11.0	43	24	33	−5	10	17	37	----	----	----	2.23	+0.4	10	5,260	e.	30	w.	3	4	9	15	7.2	22.0	13.5
Lansing	878	6	88	29.10	30.07	-----	30.4	+7.5	49	16	37	9	10	24	30	28	27	91	0.99	−0.9	10	5,270	sw.	24	nw.	13	9	5	14	6.3	7.9	0.0
Ludington	637	60	66	29.36	30.07	-----	31.1	+8.6	43	27	36	10	10	26	22	29	27	86	0.67	−1.4	9	5,858	n.	27	sw.	1	8	7	13	6.4	4.2	0.0
Marquette	734	77	111	29.25	30.08	+.03	27.6	+11.3	50	15	34	5	13	21	24	25	21	80	1.51	−0.4	12	5,942	nw.	34	nw.	13	4	9	15	7.3	15.1	8.9
Port Huron	638	70	120	29.35	30.07	+.02	29.6	+6.9	48	16	36	8	14	23	28	27	24	81	1.34	−0.6	10	6,271	nw.	26	nw.	13	6	8	14	6.9	9.1	T.
Sault Ste. Marie	614	11	52	29.37	30.10	+.07	20.8	+8.2	40	15	30	−20	10	11	41	20	18	89	1.31	−0.6	12	3,957	se.	32	nw.	13	7	6	15	6.5	15.7	5.4
Chicago	673	7	131	29.36	30.10	+.02	35.6	+9.3	54	3	41	12	14	30	26	32	28	77	0.76	−1.4	7	6,231	ne.	25	sw.	1	7	10	11	6.1	0.4	0.0
Green Bay	617	109	141	29.38	30.07	+.01	29.0	+11.6	47	25	36	−2	14	22	27	27	23	81	0.64	−0.9	4	6,217	n.	25	nw.	3	5	10	13	6.8	7.1	1.0
Milwaukee	681	125	221	29.33	30.09	+.03	33.4	+10.6	51	16	40	7	14	27	25	30	26	77	0.45	−1.4	5	7,647	n.	31	sw.	1	9	6	13	5.8	3.8	T.
Duluth	1,133	5	47	28.84	30.10	+.02	26.2	+14.8	56	24	35	−5	13	18	34	23	19	80	0.69	−0.4	3	7,316	ne.	36	nw.	13	13	6	9	4.9	9.2	5.0
North Dakota							28.3	+20.4										81	0.42	−0.1										5.2		
Moorhead	940	50	58	29.05	30.11	.00	26.2	+18.1	53	15	35	−12	9	17	37	24	21	84	0.30	−0.4	3	4,986	n.	22	nw.	25	8	8	12	6.0	3.6	T.
Bismarck	1,674	8	57	28.24	30.08	−.04	30.4	+20.1	59	15	40	0	9	21	38	26	22	77	0.74	+0.3	4	4,609	nw.	24	n.	8	12	7	9	4.7	9.9	1.3
Devils Lake	1,478	11	44	28.46	30.09	−.02	25.6	+20.5	51	15	34	−13	9	17	31	23	21	86	0.13	−0.4	3	5,377	s.	23	nw.	8	10	8	10	5.3	1.4	T.
Ellendale	1,457	10	56	28.48	30.09	-----	28.0	-----	56	15	37	−6	9	19	37	----	----	----	0.74	+0.2	7	7,642	nw.	38	e.	27	7	7	14	6.3	6.4	2.5
Grand Forks	833	12	67	-----	-----	-----	24.4	-----	46	15	33	−14	9	16	34	22	----	----	0.09	-----	2	-----	nw.	35	nw.	9	18	5	5	----	1.0	T.
Williston	1,878	41	48	28.03	30.06	−.05	31.0	+22.9	53	18	41	−2	9	21	37	26	22	76	0.19	−0.2	3	3,826	se.	31	w.	24	13	10	5	3.7	2.3	0.0
Upper Mississippi Valley							36.2	+11.6										76	1.05	−0.6										5.2		
Minneapolis	918	102	208	29.06	30.08	-----	32.0	+16.1	57	24	40	0	9	24	34	----	----	----	0.70	−0.2	4	6,098	nw.	26	nw.	3	12	4	12	5.4	7.0	2.0
St. Paul	837	236	261	29.15	30.09	.00	31.4	+15.6	57	24	40	0	10	23	33	----	----	----	0.72	−0.2	4	5,851	nw.	28	w.	7	12	5	11	4.8	7.7	3.5
La Crosse	714	11	48	29.29	30.08	.00	32.5	+13.3	59	24	41	−1	14	24	31	29	25	79	0.71	−0.4	4	2,731	s.	13	nw.	13	11	7	10	5.1	7.5	1.0
Madison	074	70	78	29.01	30.10	+.03	31.4	+12.3	48	24	28	5	14	25	23	28	26	83	0.40	−1.1	6	4,790	nw.	30	n.	28	10	6	12	5.6	3.9	0.0
Wausau	1,247	4	62	-----	30.10	-----	27.0	-----	53	24	36	−10	10	18	38	----	----	----	1.30	+0.1	5	3,354	n.	18	w.	8	8	9	11	----	12.9	3.7
Charles City	1,015	10	51	29.00	30.11	+.01	32.6	+15.5	58	24	41	5	10	24	29	28	25	80	0.61	−0.5	4	3,470	se.	18	sw.	15	14	7	7	4.1	4.3	0.0
Davenport	606	71	79	29.43	30.11	+.01	36.8	+11.9	59	27	45	11	14	29	26	32	28	75	0.14	−1.4	3	5,148	sw.	28	ne.	6	10	9	9	5.3	T.	0.0
Des Moines	861	5	99	29.17	30.11	.00	36.8	+13.1	58	27	47	10	10	27	30	31	26	70	0.09	−1.0	1	5,198	s.	27	e.	6	11	9	8	5.0	T.	0.0
Dubuque	700	81	06	20.33	30.10	+.01	34.3	+12.1	51	24	42	8	14	27	26	31	28	81	0.25	−1.1	3	3,238	s.	18	nw.	13	10	6	12	5.7	1.4	0.0
Keokuk	614	64	78	29.43	30.13	+.02	38.8	+10.5	63	3	47	14	10	30	28	33	28	71	1.08	−0.5	6	3,772	sw.	18	sw.	11	13	4	11	5.0	0.1	0.0
Cairo	358	87	93	29.70	30.10	−.02	43.8	+5.3	70	7	52	23	15	36	30	38	33	72	3.38	+0.2	7	5,460	n.	28	n.	24	10	5	13	5.8	0.0	0.0
Peoria	609	11	45	29.44	30.12	+.02	36.7	+10.8	60	3	45	13	14	29	29	32	29	81	0.83	−1.2	10	3,609	s.	17	e.	6	11	5	12	5.1	T.	0.0
Springfield, Ill	636	5	101	29.41	30.10	.00	38.6	+9.1	64	3	46	15	14	31	26	34	30	77	1.57	−0.8	10	6,542	s.	26	ne.	28	9	8	11	5.7	0.1	0.0
Hannibal	534	74	109	29.52	30.11	.00	39.3	+9.6	66	3	47	16	14	31	32	----	----	----	2.17	+0.3	7	4,228	sw.	23	sw.	11	12	3	13	5.3	1.4	0.0
St. Louis	568	265	303	29.48	30.10	−.01	41.7	+7.2	67	3	50	18	14	34	27	37	31	69	1.77	−0.8	10	6,438	n.	29	sw.	12	11	6	11	5.1	T.	0.0
Missouri Valley							38.6	+12.8										68	1.01	−0.2										4.6		
Columbia, Mo	784	6	84	29.24	30.10	−.01	40.9	+9.2	67	3	49	17	10	33	34	----	----	----	3.19	+1.2	11	4,241	n.	21	nw.	9	11	5	12	5.6	0.8	0.0
Kansas City	963	161	181	29.04	30.10	−.01	42.2	+11.0	66	2	50	17	10	34	26	36	31	70	1.24	−0.5	5	5,521	s.	24	n.	25	12	8	8	4.7	T.	0.0
St. Joseph	967	11	49	29.03	30.09	-----	40.1	-----	64	2	49	15	10	31	27	34	28	69	0.81	−0.6	4	4,342	ne.	19	sw.	15	15	6	7	4.0	T.	0.0
Springfield, Mo	1,324	98	104	28.65	30.08	−.03	43.2	+8.0	63	2	52	18	10	35	25	38	32	69	3.06	+0.7	10	5,893	se.	24	se.	22	15	7	6	3.8	0.0	0.0
Iola	984	11	50	29.01	30.09	−.01	42.7	+9.5	69	3	53	16	10	33	34	----	----	----	1.53	−0.1	6	3,864	n.	22	ne.	8	9	5	14	5.9	0.0	0.0
Topeka	087	92	107	-----	-----	-----	41.2	+10.2	66	2	50	16	10	32	32	----	----	----	1.34	−0.2	5	5,099	se.	25	sw.	15	11	9	8	4.5	T.	0.0
Lincoln	1,189	11	81	28.79	30.10	.00	38.1	+12.0	62	11	49	11	10	27	35	33	26	68	1.09	+0.1	3	4,891	s.	21	n.	28	10	9	9	5.3	0.4	T.
Omaha	1,105	115	122	28.89	30.10	−.01	38.6	+13.1	59	11	47	15	10	30	29	32	25	63	0.03	−0.9	1	4,296	nw.	21	nw.	9	17	5	6	3.6	0.4	0.0
Valentine	2,598	47	54	27.31	30.09	.00	36.1	+14.7	62	15	47	12	9	25	38	30	25	72	0.37	−0.2	5	4,513	w.	34	sw.	26	9	9	10	5.1	0.1	0.0
Sioux City	1,135	04	164	28.86	30.11	−.01	36.4	+15.4	59	24	46	12	13	27	30	31	24	64	0.04	−0.8	1	6,345	nw.	31	se.	26	14	6	8	4.2	T.	0.0
Huron	1,306	59	74	28.67	30.11	−.01	32.6	+18.3	64	15	44	4	13	21	40	27	22	70	0.19	−0.4	5	5,128	s.	25	se.	26	14	5	9	4.2	1.3	0.0
Pierre	1,572	70	75	28.37	30.08	−.03	35.8	+17.2	65	15	47	10	9	25	41	30	24	69	0.13	−0.3	4	4,520	nw.	24	nw.	8	0	11	8	4.8	0.6	0.0
Yankton	1,233	40	57	28.76	30.11	−.01	35.8	+14.9	62	15	46	12	13	25	37	----	----	----	0.11	−0.7	2	4,188	nw.	22	sw.	10	15	4	9	4.2	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope							32.7	+11.0										67	0.42	−0.3										5.3		
Billings	3,140	5	----	----	----	----	36.2	----	62	2	52	8	8	20	49	----	----	----	0.28	----	7	----	nw.	----	----	----	11	10	7	----	1.7	----
Havre	2,505	11	67	27.34	30.03	−0.04	35.6	+22.0	57	18	46	14	9	25	38	30	23	65	0.02	−0.5	1	5,397	sw.	30	sw.	18	13	10	5	4.4	T.	0.0
Helena	4,124	89	113	25.79	30.08	−.03	33.3	+10.3	59	18	42	12	8	24	33	27	19	57	0.18	−0.5	2	4,613	sw.	28	sw.	16	6	10	12	5.9	2.3	0.0
Kalispell	2,973	48	56	26.99	30.14	+.06	27.9	+4.6	49	18	34	7	9	21	20	26	23	79	0.27	−0.8	5	2,421	nw.	15	nw.	24	1	9	18	7.8	1.9	0.0
Miles City	2,371	48	55	27.49	30.10	+.01	36.3	+19.5	58	19	47	11	9	26	35	31	25	69	0.47	0.0	4	2,876	s.	21	nw.	24	14	5	9	4.8	1.1	0.0
Rapid City	3,259	50	58	26.60	30.10	+.02	36.3	+12.9	63	14	48	11	9	25	47	30	24	66	0.13	−0.4	3	3,907	n.	22	n.	24	10	7	11	5.6	0.6	0.0
Cheyenne	6,088	84	101	23.95	30.06	+.03	32.2	+4.9	57	19	42	10	13	22	33	27	20	63	0.74	+0.1	6	6,682	w.	33	w.	10	6	11	11	6.2	7.1	3.5
Lander	5,372	60	68	24.61	30.10	+.02	29.3	+6.8	52	18	42	3	13	16	35	25	19	71	0.77	+0.1	4	1,812	sw.	20	nw.	16	15	11	2	3.8	8.4	0.5
Sheridan	3,790	10	47	26.08	30.08	----	32.2	----	58	18	46	6	14	18	49	27	19	65	0.59	−0.1	5	2,130	nw.	23	nw.	26	10	10	8	4.8	4.9	T.
Yellowstone Park	6,241	11	48	----	30.17	+.07	25.2	+5.6	45	4	36	2	18	14	36	----	----	71	0.25	−1.1	8	4,108	sw.	21	n.	27	10	9	9	----	8.1	7.1
North Platte	2,821	11	51	27.07	30.06	−.01	38.6	+12.0	65	19	50	20	14	27	39	32	26	68	0.76	+0.2	3	3,654	w.	18	s.	26	10	12	6	4.8	1.0	0.0
Middle Slope							42.0	+8.2										68	1.20	+0.3										5.3		
Denver	5,292	106	113	24.69	30.03	+.02	38.8	+6.1	64	19	48	23	28	30	30	31	22	58	1.11	+0.6	7	3,931	s.	24	w.	16	5	16	7	5.4	18.0	6.0
Pueblo	4,685	80	86	25.26	30.01	+.01	38.8	+5.9	63	19	52	16	10	26	42	31	23	59	1.11	+0.6	6	3,200	nw.	23	w.	6	12	8	8	4.7	9.2	5.2
Concordia	1,392	50	58	28.59	30.10	+.01	39.8	+10.0	66	2	50	17	14	29	35	34	29	72	1.46	+0.6	3	4,309	s.	20	se.	21	8	13	7	5.2	T.	0.0
Dodge City	2,509	11	51	27.42	30.06	.00	42.6	+9.4	67	20	54	24	10	31	38	36	30	71	0.56	−0.2	4	5,413	s.	26	se.	21	12	10	6	4.4	1.3	1.3
Wichita	1,358	139	158	28.59	30.05	−.03	43.6	+9.2	64	3	52	18	10	35	28	38	33	71	0.64	−0.6	9	6,701	s.	30	s.	15	9	6	13	5.6	0.0	0.0
Broken Arrow	765	11	56	29.23	30.06	----	46.6	----	69	6	56	22	10	37	33	----	----	----	2.05	+0.7	11	7,190	n.	35	ne.	22	9	7	12	5.8	0.0	0.0
Oklahoma City	1,214	10	47	28.74	30.04	−.03	48.3	+8.7	72	6	57	27	14	40	29	42	38	74	1.48	+0.4	12	5,415	s.	22	se.	21	8	8	12	6.3	0.0	0.0
Southern Slope							49.8	+3.8										71	1.65	+0.9										5.4		
Abilene	1,738	10	52	28.20	30.03	−.02	51.4	+4.2	72	19	60	29	14	43	30	46	42	76	2.54	+1.5	8	5,152	s.	30	s.	21	11	4	13	5.6	0.0	0.0
Amarillo	3,676	10	49	26.23	30.00	−.02	45.0	+6.9	70	5	55	26	28	35	34	38	32	68	1.83	+1.1	8	5,164	sw.	24	se.	20	14	4	10	5.0	4.7	3.5
Del Rio	944	64	71	28.99	29.99	−.01	57.2	+1.2	77	22	66	41	19	48	33	51	47	75	1.04	+0.5	8	4,543	se.	29	se.	15	8	13	7	5.4	0.0	0.0
Roswell	3,566	75	85	26.35	29.99	+.01	45.4	+2.9	70	5	56	27	18	34	37	39	32	65	1.19	+0.6	8	4,385	s.	30	n.	28	8	9	11	5.8	2.1	T.
Southern Plateau							47.2	+2.4										67	1.35	+0.7										4.8		
El Paso	3,778	152	175	26.15	29.97	+.02	50.0	+1.0	66	5	59	33	24	41	28	42	34	61	0.89	+0.5	8	6,208	e.	35	w.	15	12	12	4	4.5	0.0	0.0
Santa Fe	7,013	38	53	23.18	29.99	+.01	35.6	+2.5	50	7	44	22	28	28	26	30	25	72	0.73	0.0	11	3,148	n.	17	n.	16	5	10	13	6.3	4.5	0.2
Flagstaff	6,907	10	59	23.25	29.90	−.10	33.8	+3.0	52	3	43	13	24	24	33	30	----	78	2.10	----	9	3,493	sw.	23	n.	28	6	10	12	----	15.5	T.0
Phoenix	1,108	10	107	28.78	29.94	−.05	57.8	+2.7	80	3	68	38	24	48	34	50	42	63	3.71	+2.9	8	2,893	e.	23	nw.	19	8	12	8	5.1	0.0	0.
Yuma	141	9	54	29.80	29.95	−.05	59.4	+0.8	79	3	71	38	23	48	33	51	43	60	1.13	+0.7	6	2,625	ne.	27	nw.	19	15	10	3	3.3	0.0	0.0
Independence	3,957	6	27	25.94	30.00	−.06	46.6	+4.4	66	28	59	24	23	34	34	37	----	----	0.31	−0.5	2	----	nw.	----	----	----	13	4	11	----	0.0	0.0
Middle Plateau							37.0	+3.6										70	0.66	−0.4										6.1		
Reno	4,532	74	81	25.44	30.04	−.04	39.5	+3.9	59	18	51	20	20	28	32	34	27	63	0.47	−0.7	4	2,328	w.	27	w.	18	10	11	7	5.1	T.	0.0
Tonopah	6,090	12	20	----	----	----	36.7	----	55	18	44	16	22	29	22	32	27	70	0.57	----	5	----	se.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.62	30.07	−.02	37.2	+3.7	58	1	49	15	22	25	37	32	25	66	0.51	−0.4	6	4,403	ne.	24	nw.	19	11	10	7	4.6	T.	0.0
Modena	5,473	10	43	24.58	29.98	−.06	34.9	+3.9	54	18	43	19	23	27	30	31	28	80	0.88	−0.1	8	4,036	e.	24	e.	12	4	9	15	7.0	3.0	0.0
Salt Lake City	4,360	163	203	25.64	30.10	+.02	34.0	+0.2	53	18	39	22	2	29	22	31	27	77	0.61	−0.9	8	2,976	nw.	24	se.	19	6	7	15	7.0	2.0	0.0
Grand Junction	4,602	60	68	25.36	29.96	−.08	39.2	+6.3	57	26	49	23	2	30	31	33	27	65	0.81	+0.2	11	2,652	se.	17	nw.	27	4	8	16	7.0	0.4	0.0
Northern Plateau							35.3	+2.1										74	0.64	−0.7										6.6		
Baker	3,471	48	53	26.50	30.17	+.05	30.9	+1.9	46	18	40	13	7	22	25	28	25	77	0.51	−0.7	8	3,209	se.	16	se.	18	4	12	12	6.2	3.7	0.0
Boise	2,739	79	87	27.25	30.17	+.05	36.2	+1.4	54	14	45	23	8	28	24	32	27	71	0.84	−0.6	8	2,597	se.	20	nw.	19	8	9	11	5.8	0.1	0.0
Lewiston	757	40	48	29.33	30.16	+.05	39.5	+2.5	56	14	47	23	9	32	29	----	----	----	0.88	−0.4	9	1,604	e.	1	7ne.	17	3	9	16	7.3	T.	0.0
Pocatello	4,477	760	68	25.51	30.16	+.06	29.0	+0.1	47	18	37	9	25	20	33	26	23	78	0.42	−0.8	7	4,104	se.	28	sw.	16	8	10	10	5.6	3.6	0.0
Spokane	1,929	101	110	28.04	30.14	+.05	34.6	+3.3	54	18	41	18	12	28	24	32	28	76	0.76	−1.0	8	2,981	s.	21	s.	18	4	10	14	6.9	2.6	0.0
Walla Walla	991	57	65	29.05	30.14	+.03	39.0	+1.9	61	18	45	25	9	33	22	36	31	76	0.90	−0.9	10	2,661	s.	21	s.	19	3	9	16	7.7	T.	0.0
Yakima	1,076	58	67	28.96	30.13	----	38.2	+3.7	60	17	47	24	14	30	26	34	27	64	0.15	−0.8	3	2,378	n.	28	s.	18	7	8	13	6.4	0.5	0.0
North Pacific Coast Region							44.9	+3.0										75	3.44	−1.7										7.1		
North Head	211	11	56	29.82	30.06	.00	46.5	+3.5	59	2	51	37	21	42	14	43	39	76	4.95	−2.5	15	9,722	se.	58	sw.	18	4	8	16	6.9	0.0	0.0
Port Angeles	29	8	53	----	30.06	----	42.1	----	51	18	48	32	6	36	16	----	----	----	3.25	0.0	12	3,551	s.	26	sw.	15	5	10	13	----	0.0	0.0
Seattle	125	215	250	29.92	30.05	−.01	44.4	+3.3	62	13	50	35	21	39	23	41	36	72	3.25	−0.6	13	5,400	se.	33	sw.	15	5	12	11	6.5	0.0	0.0
Tacoma	194	172	201	29.85	30.06	.00	43.5	+2.9	60	13	50	31	13	37	29	----	----	----	3.38	−1.3	13	4,849	s.	36	sw.	15	4	9	15	6.8	0.0	0.0
Tatoosh Island	86	9	53	29.90	30.00	.00	45.6	+4.6	55	3	48	38	26	43	9	43	40	83	7.41	−2.0	18	11,687	e.	49	s.	17	5	3	20	7.5	0.0	0.0
Medford	1,329	29	58	28.63	30.06	----	43.8	----	66	12	56	24	6	31	40	39	34	72	1.06	−1.3	9	----	s.	26	w.	18	5	11	12	6.8	T.	0.0
Portland, Oreg	153	68	106	29.92	30.08	.00	45.0	+2.9	58	18	51	32	22	39	19	41	35	70	2.40	−3.0	12	3,560	e.	24	sw.	18	2	8	18	7.8	0.0	0.0
Roseburg	510	75	99	29.52	30.08	−.02	44.5	+1.1	64	28	53	28	24	36	30	42	38	78	1.80	−2.7	14	1,995	nw.	19	s.	25	2	11	15	7.4	0.	0.00
Middle Pacific Coast Region							53.4	+3.5										76	1.53	−2.4										5.8		
Eureka	62	73	89	30.00	30.07	−.04	49.8	+2.6	62	17	56	37	20	44	23	48	45	85	2.39	−4.1	10	3,369	n.	35	n.	23	6	11	11	6.1	0.0	0.0
Red Bluff	330	5	58	29.66	30.02	−.09	52.7	+3.3	75	28	62	37	25	43	32	47	40	68	1.61	−2.3	7	3,277	nw.	24	n.	23	9	3	16	6.2	0.0	0.0
Sacramento	69	106	117	29.93	30.00	−.09	53.4	+3.3	68	24	61	39	21	45	24	50	47	80	1.35	−1.7	7	3,765	nw.	24	nw.	19	11	7	10	4.8	0.0	0.0
San Francisco	155	208	243	29.84	30.01	−.09	56.7	+4.5	69	28	62	48	23	51	20	51	46	72	1.10	−2.8	12	3,369	w.	26	w.	25	8	10	10	5.8	0.0	0.0
San Jose	141	12	110	29.87	30.02	----	54.6	+4.0	71	28	63	37	21	46	32	----	----	----	1.20	−1.2	9	2,740	nw.	22	nw.	19	7	9	12	6.3	0.0	0.0
South Pacific Coast Region							58.0	+4.1										69	2.68	+0.5										5.2		
Fresno	327	89	98	29.65	30.01	−.07	54.2	+3.1	69	18	64	35	20	45	27	49	44	73	0.67	−0.8	7	2,988	nw.	33	nw.	19	9	7	12	5.5	0.0	0.0
Los Angeles	338	159	191	29.60	29.96	−.10	60.7	+5.2	75	18	68	49	21	53	24	51	44	60	3.25	+0.2	7	3,722	ne.	24	n.	19	12	8	8	4.7	0.0	0.0
San Diego	87	62	70	29.87	29.96	−.10	59.2	+4.1	77	2	66	44	22	52	24	54	50	75	4.11	+2.1	9	3,557	e.	27	s.	3	8	10	10	5.4	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.86	29.95	----	75.4	+0.5	87	5	80	66	18	70	18	----	----	----	5.84	+3.1	13	7,113	e.	42	n.	6	8	10	10	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	----	[1]29.83	−.02	81.2	+0.9	93	28	90	70	7	72	21	----	----	[1]74	T.	−0.8	0	6,510	n.	25	nw.	7	1	24	3	5.5	0.0	0.0
Cristobal	36	6	97	[2]29.83	[1]29.86	−.03	81.8	+1.0	87	3	86	73	17	78	14	74	72	[1]75	0.97	−0.6	12	9,080	n.	29	n.	5	6	17	5	5.5	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]29.03	[2]29.58	----	5.2	----	40	2	16	−28	28	−6	40	6	1	71	0.42	----	6	1,199	n.	19	sw.	2	7	4	17	7.1	6.2	12.5
Juneau	80	11	50	[2]29.60	[2]29.69	----	36.2	----	45	12	40	28	14	33	11	35	32	85	8.26	----	25	4,984	se.	31	se.	21	0	2	26	9.2	12.1	1.1
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.09	[2]30.13	----	72.2	+1.4	78	17	76	65	4	68	11	65	62	72	0.50	−3.2	13	7,366	e.	29	e.	24	10	16	2	4.3	0.	0.0

[1] Observations taken bi-hourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, February, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				30.2		36.2	24.3	44	0	8.09		17.0
Sydney, C. B. I	48	29.80	29.85	−0.07	25.7	+6.4	32.4	19.0	42	−11	8.70	+4.61	35.0
Halifax, N. S	88	29.76	29.87	−.08	26.7	+4.3	33.1	20.4	44	−3	4.07	−1.09	8.8
Yarmouth, N. S	65	29.78	29.85	−.14	28.3	+2.5	34.2	22.4	45	5	5.62	+1.45	23.3
Charlottetown, P. E. I	38	29.77	29.81	−.14	21.9	+4.3	28.1	15.6	45	−6	5.22	+2.16	48.8
Chatham, N. B	28	29.81	29.85	−.11	17.7	+5.2	26.7	8.8	44	−25	2.77	−0.39	14.2
Father Point, Que	20	29.95	29.98	.00	14.7	+3.2	22.3	7.1	38	−13	1.94	−0.27	19.4
Quebec, Que	296	29.69	30.03	+.04	15.0	+3.2	21.7	8.2	37	−16	2.54	−0.73	25.4
Doucet, Que	1,236				3.9		20.2	−12.4	45	−48	1.34		13.4
Montreal, Que	187	29.80	30.02	.00	18.5	+4.0	25.9	11.1	36	−4	3.12	+0.05	23.7
Ottawa, Ont	236	29.76	30.05	+.03	17.6	+5.9	28.0	7.3	44	−16	1.49	−1.20	14.2
Kingston, Ont	285	29.72	30.06	+.02	21.9	+4.1	30.4	13.4	40	−8	1.17	−1.37	5.6
Toronto, Ont	379	29.64	30.07	+.03	26.6	+5.1	33.2	20.0	43	0	1.13	−1.48	9.5
Cochrane, Ont	930				10.0		19.5	0.6	38	−27	0.30		3.0
White River, Ont	1,244	29.68	30.06	+.04	10.4	+10.2	26.0	−5.1	42	−41	0.67	−0.85	6.7
London, Ont	808				26.8		33.9	19.8	44	2	1.99		13.8
Southampton, Ont	656	29.32	30.06	+.04	23.6	+3.7	31.1	16.2	42	−5	0.96	−1.94	8.7
Parry Sound, Ont	688	29.34	30.07	+.06	19.0	+4.7	27.3	10.7	37	−22	1.47	−1.45	14.6
Port Arthur, Ont	644	29.36	30.10	+.05	21.5	+15.1	29.8	13.3	40	−11	0.24	−0.66	2.4
Winnipeg, Man	760	29.24	30.11	+.01	17.9	+19.5	26.3	9.5	40	−21	0.18	−0.80	1.8
Minnedosa, Man	1,690	28.20	30.10	+.01	19.2	+21.9	29.3	9.2	41	−28	0.06	−0.55	0.6
Le Pas, Man	860				15.6		26.5	4.8	44	−23	0.11		1.1
Qu'Appelle, Sask	2,115	27.70	30.01	−.07	25.9	+26.5	35.2	16.6	45	−16	0.22	−0.51	2.2
Moose Jaw, Sask	1,759				31.2		43.0	19.4	58	−1	0.07		0.7
Swift Current, Sask	2,392	27.36	29.94	−.13	31.6	+23.6	43.9	19.4	60	5	0.07	−0.67	0.7
Medicine Hat, Alb	2,144												
Calgary, Alb	3,428												
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.40	30.03	−.06	22.2	+25.2	33.8	10.7	45	−12	0.16	−0.53	1.6
Battleford, Sask	1,592	28.20	29.99	−.10	26.6	+26.5	37.5	15.6	53	−2	0.03	−0.34	0.3
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.77	30.03	+.03	43.1	+3.6	47.4	38.9	51	32	3.22	−0.88	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

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Toronto, Ont	379	29.58	30.01	−.04	24.9	+3.5	31.6	18.2	45	0	2.62	−0.30	22.5
Estevan Point, B. C	20				44.3		49.9	38.7	57	30	18.63		0.0
Prince Rupert, B. C	170				42.6		46.6	38.6	57	30	14.08		0.0

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NOTES ON LAKE LEVELS

By JESSE W. SHUMAN, C. E.

[Minneapolis, Minn., January 29, 1930]

In Chapter III of his book, Brückner (1) investigates the secular oscillations of lakes without outlets. He studied the Caspian Sea, Great Salt Lake, Lake George, and numerous others in various parts of the world. He sets up five general theses—

(1) Oscillations of lakes with complete outflow are small and follow without much lag, the oscillations of the various water supplies (inflows, springs, etc.)

(2) Oscillations of lakes without outlets are great, and show a very considerable lag in fluctuations, in comparison with the oscillations of their water supply. This lag may be so great that the maximum of the mean water level may not occur until the water supply has passed its peak and receded to its mean value.

(3) Lakes without outlets, whose inflowing rivers or water supplies have pronounced oscillations, show but little lag, and their oscillations are only a small per cent of those of the water supply. The same holds for lakes with level flat shores, in contrast with those having steep shores.

(4) Secondary oscillations of the water supplies, for a no-outlet lake, have no effect upon the latter as long as these oscillations are of small intensity and interfere in their flow with one another. The storage curve of the levels behaves similarily—the rise and fall is either accelerated or delayed.

(5) Lakes with partial, incomplete outlets stand in their behavior between complete outflow and no-outflow lakes.

Brückner now discusses the behavior of the various lakes, fortified with all the available data he could accumulate, both from recorded observations and indirectly obtained, and tabulates the results. Table 1, is a greatly abbreviated presentation of these results, and is given for the purposes of record. These data were assembled over 40 years ago, and with the accumulated observations since that time, should be of unique interest and assistance to a present-day investigator.

It will be noted that Brückner gives data on 7 lakes from 1600 to 1800 A. D. Their rise and fall being also compared to the advance and retreat of the Alpine glaciers. The rhymic swings seem to be well in step with one another. From 1800, the table gives data on 10 lakes in Europe, 11 in Asia, 2 in South America, 4 in North America, 6 in Africa, and 3 in Australia. All of these lakes are without outlets, the better known being: Caspian Sea; Lake George in Australia; Valencia in South America; Honey, Pyramid, and Great Salt Lake in North America.

At the end of Chapter III, Brückner closes with the following: "As the oscillations of the lake levels are of the same nature and occur at the same time, so must also the climatic changes for the countries of the world be similar and occur at the same time. This must be so. Is it possible that climatic oscillations can exist alone (with no effect upon anything else)? Which are the meteorological elements whose changes cause the variations in the lake levels? So far, we are completely in the dark, as the plotting of the meteorological observations alone will not determine it. At any events, it can only be the temperature that is active, which regulates the evaporation, or the rainfall, upon which the supply to the lake depends—perhaps it may be both at the same time. The influence of one oscillation in temperature is not to be underestimated; as first of all, it effects the evaporation from the surface of the lake, hence the level; then also the evaporation of the rain falling on the land, which influences the water supply. Also the effect of an oscillation in rainfall must be twofold—one direct in so far as the abundance of water is determined, which governs the inflow, and one indirect, inasmuch as hand to hand with the rainfall changes, the ratio of clouds vary, which in turn effects the evaporation. We do not know which alone of these factors to ascribe the principal work. We can only say the maximum of the lake levels seems to occur during a cool or wet to cool and wet, and the minimum of the levels to occur during a dry or warm to dry and warm, periods of weather. Quite definite is the conclusion that we can draw from the variation of the lake levels, relative to the position of the peak of the climatic oscillations. The former must not lag inconsiderably behind the latter. The peak of the latter must occur before the peak of the lake level oscillations. How great this lag of the lake is, we have not yet determined—and it must vary from lake to lake. Herein we have, perhaps, an explanation of the different behavior of the individual lakes from their neighbors. At any event, however, the periods of the lake level oscillations happen to occur, with respect to analogous portions of the curve of climatic oscillations, either at periods of maximum to (cold or wet) to (cold and wet), or at periods of minimum to (warm or dry), to (warm and dry)—certainly the same relationship continues to the end of the record. A general idea of lake-level oscillation is given in the following:

Dry or warm to dry and warm	Wet or cold to wet and cold
1720	1740
1760	1780
1800	1820
1835	1850
1865	1880

We know enough from what we have given above about the Caspian Sea, as well as for various lakes, whose meteorological data we have assembled and discussed (Table 1) in detail, to point out the reason for these

oscillations. We will reserve this for later consideration. Sufficient here to say that all over the world, wherever there are lakes without outlets synchronous oscillation exists.

TABLE 1.—*Lakes without outlets up to 1800 A. D.*

[Condensed from the original]

	Alpine glaciers	Caspian Sea
Maximum about 1600	Increase 1595 to 1610	High 1838.
	Increase 1677 to 1681	
	Increase 1710 to 1716	
Minimum about 1720		Low 1715 to 1720.
Rising		Rising.
Maximum about 1740		Maximum 1742 to 1743.
Falling	Decrease 1750 to 1767	Falling.
Minimum about 1760		Minimum 1765 to 1766.
Rising	Increase 1760 to 1786	Rising.
Maximum about 1780		From 1780 (?) higher levels to 1809-1814.
Falling	Slight falling	

Lakes without outlets since 1800 A. D.

	North America			South America—Lake of Valencia	Australia—Lake George
	Honey Lake	Pyramid-Winnemucca	Great Salt Lake		
Minimum about 1800.				Low, 1800	Dry, about 1800.
Rising				Rising	Rising.
Maximum about 1820.				May, 1822, or a little later.	Maximum, 1822 or 1823.
Falling				Falling	Falling.
Minimum about 1835.				Minimum, 1835 (?)-1841.	Dry, 1838-1850.
Rising					Rising.
Maximum about 1850.			Moderate maximum, 1856.		Moderate maximum, 1852.
Falling			Falling		Falling.
Minimum about 1865.	Dry, 1859-1863.	Low, 1862	Minimum, 1861.		Dry, 1859.
Rising	Rising so that bigb in 1867.	Rising from 1867 on.	Rise before 1867.		Rising.
Maximum about 1880.		High in the 70's.	High ln the 70's.	Maximum, 1873-1874; high until 1877.	Maximum, 1894.
Falling		Beginuing in the 80's still higher than in 1862.	Falling until 1889.		Falling.

After discussing secular variation of rivers and lakes with outlets, rainfall, and barometric pressure Brückner deals, in Chapter VII, with secular variation in temperature, and certain relationships are disclosed in the following:

TABLE 2.—*Secular variation*

Lakes	Rainfall	Temperature
	Dry, 1716/25	
Minimum, 1720	Wet, 1736/55	Cold, 1731/45.
Maximum, 1740	Dry, 1756/70	Warm, 1746/55.
Minimum, 1760	Wet, 1771/80	Cold, 1756/90.
Maximum, 1780	Dry, 1781/05	Warm, 1791/05.
Minimum, 1800	Wet, 1806/25	Cold, 1806/20.
Maximum, 1820	Dry, 1826/40	Warm, 1821/35.
Minimum, 1835	Wet, 1841/55	Cold, 1836/50.
Maximum, 1850	Dry, 1856/70	Warm, 1851/70.
Minimum, 1865	Wet, 1871/85	Cold, 1871/85.
Maximum, 1880		

As is well known, Brückner determined from his studies that the length of the period of oscillation in our weather elements was about 36 years, and he points to the above table as indicating this in all three columns. He calls attention to the lag of rainfall behind temperature changes; also in further discussing temperature changes he makes the statement: "There is no doubt but that temperature oscillations are primary, and those of barometric pressure and rainfall are secondary."

Despite Brückner's classical and published studies regarding lakes, but little attention, if any, has been given them by American investigators. The rise and fall of the Great Lakes and Great Salt Lake, have received current newspaper comment from time to time, the oscillations of the former giving rise to some very expensive lawsuits; and while eminent engineers have dealt in their reports regarding the levels of the Great Lakes, and have ascribed climatic changes as the cause, it has been only in a decidedly vague manner.

Streiff (2) first pointed out that the Great Lakes and Great Salt Lake were oscillating in accordance with the cycle discovered by Brückner, and later (4) again referred to these lakes as well as Lake George in Australia. Inasmuch as public interests are much concerned with lake levels, and as so many of our smaller lakes are at extremely low levels, it is thought that these notes might throw additional light on the subject of their oscillations.

The various cycles referred to in these notes, have the following significance:

Secular cycle: The dictionary defines the word "secular," as brought about in the course of ages; occurring or observed once in an age or century. Brückner constantly refers to the secular variation in rainfall, temperature, lake levels, etc., and evidently means thereby the long swing in the climatic elements. Streiff (4) refers to secular cycle as being of variable periodicity, the last three periods being estimated at 70, 60, and 90 years in length, giving an average of about 73 years—the first period being estimated from Douglass's sequoia curve (1911, 11 trees). We adopt Streiff's nomenclature for the meaning of the secular cycle.

Wolf numbers or sunspot secular cycle: This is the long swing in the Wolf numbers; this cycle being low at 1816, high about 1856 and low again about 1906. From 1816 to 1906 is 90 years. This is the same cycle, evidently, as found in tree-ring growth.

Double secular cycle: It is shown in these notes that the secular variation of rainfall, temperature and lake levels appears to be such that there are two HIGHS for ONE of the Wolf numbers secular HIGH—giving rise to what is here called a double secular cycle (double the number of peaks, as in the Wolf numbers secular).

Wolf, solar cycle: By this is meant the cycle of approximately 11 years, the period from sun spot maximum to maximum. This is variable, also.

Double Wolf cycle: This is a cycle of half the solar or Wolf period; it has double the number of peaks as the Wolf. Again, this is Streiff's nomenclature.

Brückner cycle: This cycle is described by Streiff (4) as having twice the solar cycle period, or approximately 22.6 years. It is a variable, depending upon the actual length of two solar cycles. In his book, Brückner shows his cycle as having a variable periodicity, with an average of plus or minus 35 years. But as pointed out by Streiff (4), Brückner did not separate his cycle from what we now call the secular cycle.

HIGH, LOW: These terms in reference to cycles, herein, designate the periods of maximum and minimum values of the ordinates of the cycles.

Figure 3 shows the data on secular variation of rainfall, lake levels, and temperature, as found by Brückner, Table 2, plotted only to show the peaks and troughs at various times, without regard to vertical scale. We note the 30 to 45 year periods that are present in all three graphs. The lag of the lake levels behind the rainfall, and of the rainfall behind the temperature (wet after cold

and dry after warm) is clearly indicated. Brückner's cycle, to him, consisted of twice the solar (4) cycle superimposed upon the Wolf numbers secular cycle, and this latter cycle has been traced in on one of the graphs of Figure 3. It will be noted that there are two HIGHS and two LOWS of the lake levels, for one of the Wolf numbers, secular cycle. Curves are also submitted, accompanying these notes, covering:

Figure 1, Rainfall at Padua, Italy.
Figure 2, Wolf numbers, mean annual smoothed.
Figure 4, Lake Ontario mean annual levels.

weather. These wet periods are reflected in lake levels, as will be shown later. This Padua rainfall record is one of the longest available, and is given here to show that while the Wolf numbers, secular cycle, affects the general swing up and down, the Brückner cycle also operates, and produces more HIGHS and LOWS than the former cycle. It seems probable that the same type of behavior may be expected all over the world, as in every record of rainfall examined by the writer, the Brückner and secular cycles are present. Sometimes they are very faint, but nevertheless present. Also because of the fact that lakes

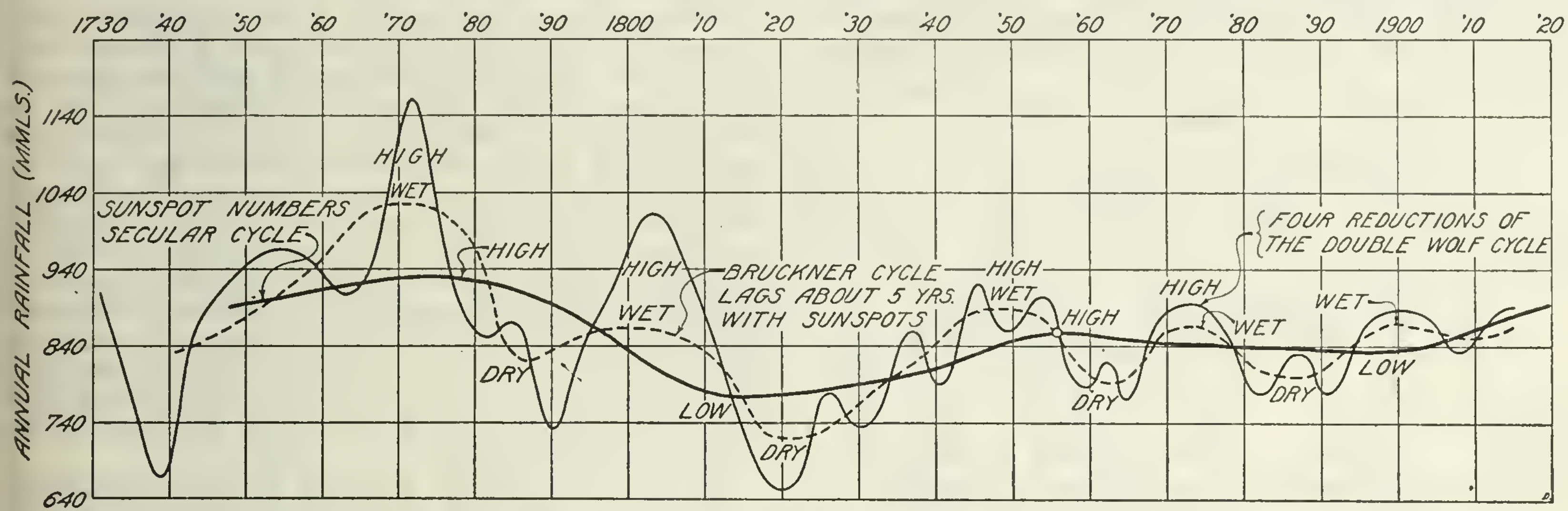

FIGURE 1.—Annual rainfall at Padua, Italy. Note a wet period occurs each side of sun-spot secular HIGH (the crests) of Brückner cycle

Figure 4, Mean annual temperature at Toronto, Canada.
Figure 4, Mean annual temperature at Detroit, Mich.
Figure 5, Mean annual temperature at Sidney, Australia.
Figure 5, Mean annual levels of Lake George, Australia.
Figure 5, Mean annual temperature at Bucharest, Rumania.
Figure 5, Mean annual departure of Caspian Sea levels.
Figure 5, Mean annual temperature at Salt Lake City.
Figure 5, Mean annual levels of Great Salt Lake.

all over the world show certain synchronous swings, as found by Brückner, we may accept this as a fact, until it is disproved by bringing forward a series of raw data, which will fail to yield these cycles.

The curve of smoothed Wolf numbers, Figure 2, is submitted for comparison purposes, showing the Brückner cycle, superimposed on the secular cycle.

Taking up the lake levels, we refer first to curve No. 10, Figure 5, Lake George. Streiff's data (4) for this lake from 1852 to 1905 has been pieced out by data taken from Brückner's book, and the resulting graph gives a

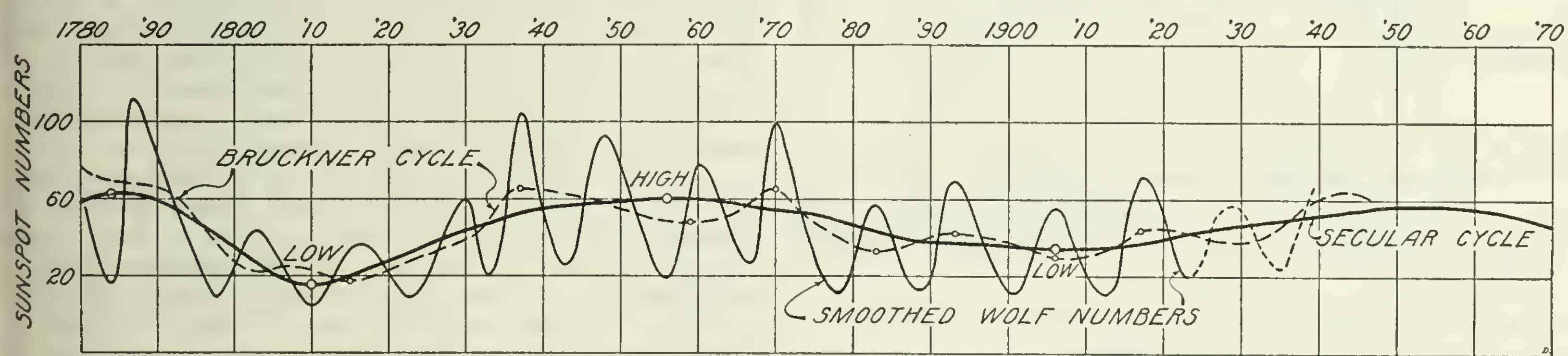

FIGURE 2.—Smoothed Wolf numbers

Figure 6, Lake Ontario cycle analysis.

Considering the Padua rainfall, this is a graph of the annual values greatly reduced, or smoothed. Four reductions were first used to secure the double Wolf cycle, and the latter values were again reduced four times, giving the curve as plotted. The median line drawn through the loops of this curve, gives us the Brückner cycle, and a median line through the latter gives us the Wolf numbers, secular cycle, which was HIGH about 1780 and 1856, and LOW about 1815 and 1900. It will be noted that there is a *crest* of the Brückner cycle on *each* side of (before and after) the HIGH of the secular cycle, which gives rise to two periods of wetter than normal

very good picture of how no-outlet lakes behave in the extreme. The sun-spot secular is shown in heavy smooth line, and the lake-level secular in dotted line. The Brückner cycle oscillates about the double or lake-levels secular, and the latter about the sun-spot numbers secular cycle. In October, 1929, Streiff (4) writes that this lake is already half full again. The curves indicate that a period of high levels is impending. A local Minneapolis newspaper, February 21, 1928, says, in a dispatch from Melbourne, Australia: "Fourteen persons are dead to-day and many are missing in what is believed to be the worst floods in the history of Australia—landslides were occurring at many points—damage to the town of

Grafton alone estimated at $3,750,000—water was 20 feet deep in some streets of Murwillumbah—the Brisbane River in Queensland district already is 26 feet above normal and is rising at the rate of 6 inches an hour." From the foregoing it is quite probable that Lake George will again attain the levels obtaining in the seventies to eighties.

Curve No. 9, Figure 5, is a graph of the mean annual temperature at Sidney, Australia. The solar, Brückner, and secular cycles have been traced in. Note the HIGH of the secular is about 1906, just opposite the LOW period of the Wolf numbers secular; and the LOW at 1875 is opposite the high period of lake levels, and about 19 years after 1856, the former HIGH of the Wolf numbers

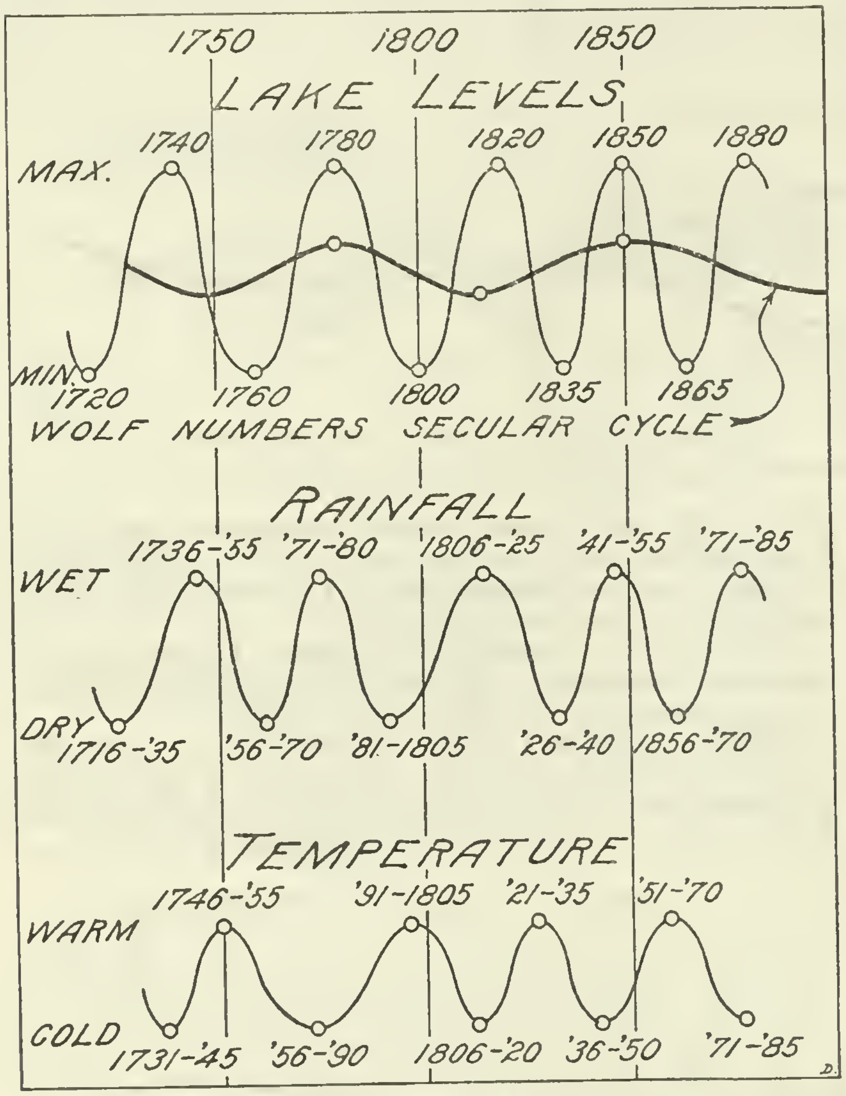

FIGURE 3.—Secular oscillation of lake levels, rainfall, and temperature. (From p. 236 of Brückner's Klimaschwankungen seit 1700.) Rainfall lags behind temperature, wet after cold, and lake levels behind rainfall

secular. It is self-evident, when we come to make these comparisons, as plotted, considering the cycles, that temperature alone must greatly affect lake levels, as at higher temperatures the evaporation must be greater, and vice versa. Thus, HIGH of the temperature secular is synchronous with low lake levels, and LOW of temperature secular with high lake levels.

Attention is directed to the HIGH of the temperature secular at about 1850 (see temperature curve No. 8, fig. 4, for Detroit, going back to 1940), close to Wolf numbers secular HIGH, as well as a HIGH about 1905, the LOW point of the Wolf numbers secular. It is known that the sun's heat output is slightly greater at sun-spot maxima, also this applies to high region of the sun-spot secular. Apparently also the mean temperature on the earth is higher at the LOW period of sun-spot numbers, i. e., 1905, as shown in all temperature graphs. Perhaps there is a decrease in the sun's heat output during sun-spot minima (and at LOW of its secular), but in any event there must be fewer clouds, with a net result of higher than normal temperature. This must be a fact, as examination of rainfall graphs everywhere indicate much less rain at the LOW periods of the Wolf numbers secular cycle. Thus the combined effect of rainfall and temperature on lake levels is to give a secular periodicity to the latter of approximately one-half of the period of the Wolf numbers secular, all as originally shown in Brückner's discussions and data.

Referring now to curves No. 11 and 12, Figure 5, temperature at Bucharest and mean annual departures of Caspian Sea levels, the same cycles as discussed above are present. While Bucharest is a long way from the Caspian Sea, it is still believed that the trends of temperature (all annual fluctuations ironed out) are very close to that of the actual contiguous area of the Caspian. Brückner's data on the Caspian stops at 1878, but there can be but little doubt as to the probable behavior of levels of the sea since that time. It must have been low about 1900 to 1910, and has undoubtedly been since rising, much as has Lake George. It may be noted that the HIGH levels of the 1870's accompanies the LOW period of the temperature secular; also that the annual peaks in the levels follow, by a few years, the LOWS of the temperature solar cycles.

Curves No. 13 and 14, Figure 5, give the temperature, at Salt Lake City, and the mean annual levels of Great Salt Lake (5). This lake has behaved identically with Lake George and the Caspian Sea. It has oscillated over 14 feet between 1873 and 1905. Note that the annual HIGH levels occur about the same time as the crests of the solar temperature cycles, and that these HIGH levels are really lagging behind the former LOWS of the temperature solar cycles. Streiff (4) has already pointed out the impending higher levels of this lake. The last LOW of the temperature solar cycle (curve No. 13) was about 1927–28; and judging from former behavior, the levels are about due to begin their rise (i. e., increased rainfall for the ensuing period is indicated). The Minneapolis Journal of July 1, 1930 states, in a dispatch from Tonapah, Nev.: "Nevada's forbidding desert *often* forsaken by its hardy horned toads and lizards, through a caprice of nature, has again become a haven for countless living things. Rain falling 19 successive days [1] recently transformed barren wastes into one brilliant flower bed. With abundant foliage to feed upon, insect life has multiplied until the great desert is alive with creeping creatures." The ensuing LOW of the temperature secular, about 1935 to 1940, will doubtless mark the culmination of these HIGH levels. Again, the Minneapolis Journal says, January 7, 1931: "Great Salt Lake, one of the saltiest lakes in the world, has succumbed to the cold. Ice was found on the lake yesterday for the first time in the history of the Weather Bureau."

The 19 days of successive rainfall and the formation of ice are simply climatic witnesses, in this region, to what is to follow. The word "often" italicized above by the writer, is significant in that it indicates in a general newspaper dispatch the fact that similar phenomena have occurred before. It is also interesting to note that this wet period at Tonapah came about at the same time as portions of the United States in the East were suffering from one of their worst droughts. This is

[1] This is not strictly accurate; the longest period of days with measurable rain in Nevada for May, 1930, was 11 and the total catch for the 11 days was 1.61 inches. The rainfall average for the State was 2.20 inches or 204 per cent of the May average.—*Editor*.

simply a concrete demonstration of the variation in phase of the Brückner cycles in weather elements in different parts of the country.

Inasmuch as Brückner, by his method of reduction of the raw or observational data did not separate the Brückner from the secular cycle, as we now understand the Brückner cycle (twice the solar cycle period), it appeared to him, just as shown in the examples above that the phase of this cycle plus or minus 35 years, was the same all over the world. If we separate the two, in meteorological data, we will find the phase of the secular cycle to be the same all over the world, and that of the Brückner cycle to vary, either leading, in phase with, or lagging behind the Brückner cycle in Wolf numbers. For the various lakes without outlet, here shown, the phase of the Brückner cycle is about the same, although this is not conclusive that it would be so for every no-outlet lake. For lakes with outflows, the phase of the Brückner cycle varies with the geographic location; viz, for Lake Ontario, the Brückner cycle seems to lead sun spots about 8 years. However, it is fairly easy to detect the Brückner cycle in any lake-level series, having a continuous fairly reliable record, and after levels data have been accumulated covering two complete Wolf numbers secular cycle swings, the behavior of lake levels will be more thoroughly understood.

Temperature oscillations do have a great effect upon the levels as shown by the examples given, and rainfall has not been considered here, because this element has generally been used as the basic active agent in affecting lake levels. More intimate knowledge, of course, can be gained regarding a lake's behavior in levels, by investigating rainfall and temperature together at the same time as levels. The purpose of these notes, however, is to show the reason for the double secular cycle, apparent in lake levels, and the effect of temperature. Securing the average rainfall and temperature (from all stations) surrounding a lake region will give slightly different results, in annual values, but the trends, cycles derived therefrom will not greatly differ from those of a single station in the vicinity if anomalies be taken into account. For quantitative studies, actual mean or average data on the basin should, of course, be taken.

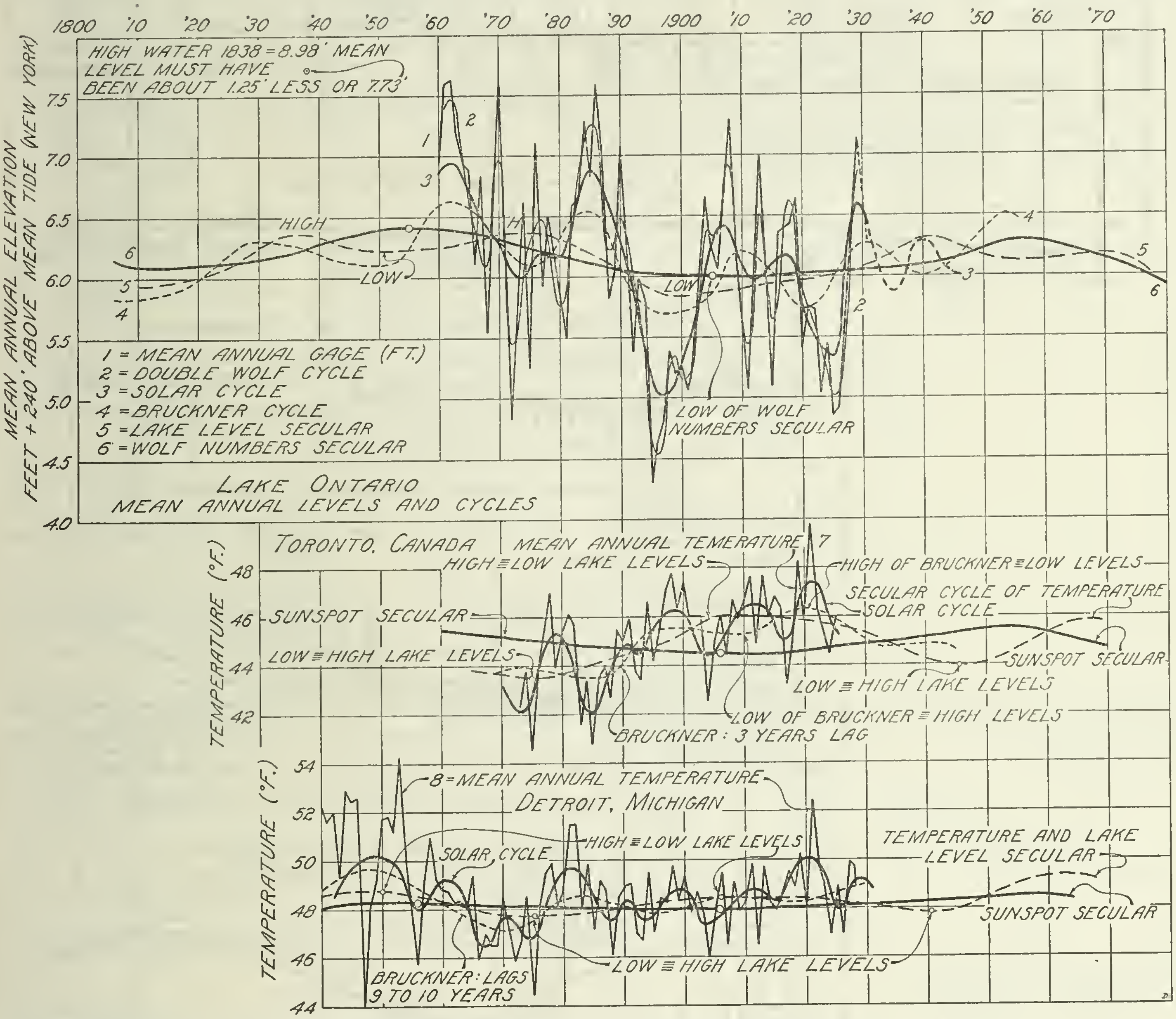

Figure 4.—Lake Ontario levels and cycles. Comparing the Toronto curve with that of Detroit, the Brückner cycle in former lags three years and in the latter lags nine years behind sun-spots trend, yet the secular cycle phases are identical

The fact that the phase of the Brückner cycle in both temperature and rainfall may differ in different parts of the country or world, explains very nicely just why

Brückner found, see his Table 1, some difficulty in matching up the periods of the lake oscillations; the HIGH lake levels, occurring as the LOWS of the temperature and the HIGHS of the rainfall secular cycles combined together, the occurrence of this event differing from place to place.

increased run-off and higher lake levels during wetter than normal weather is due, according to the opinion of the writer, to the effect of temperature. It is evident that as the secular trend of the temperature of a district reaches its LOW, the evaporation from the ground and the lakes therein must diminish, and this period is

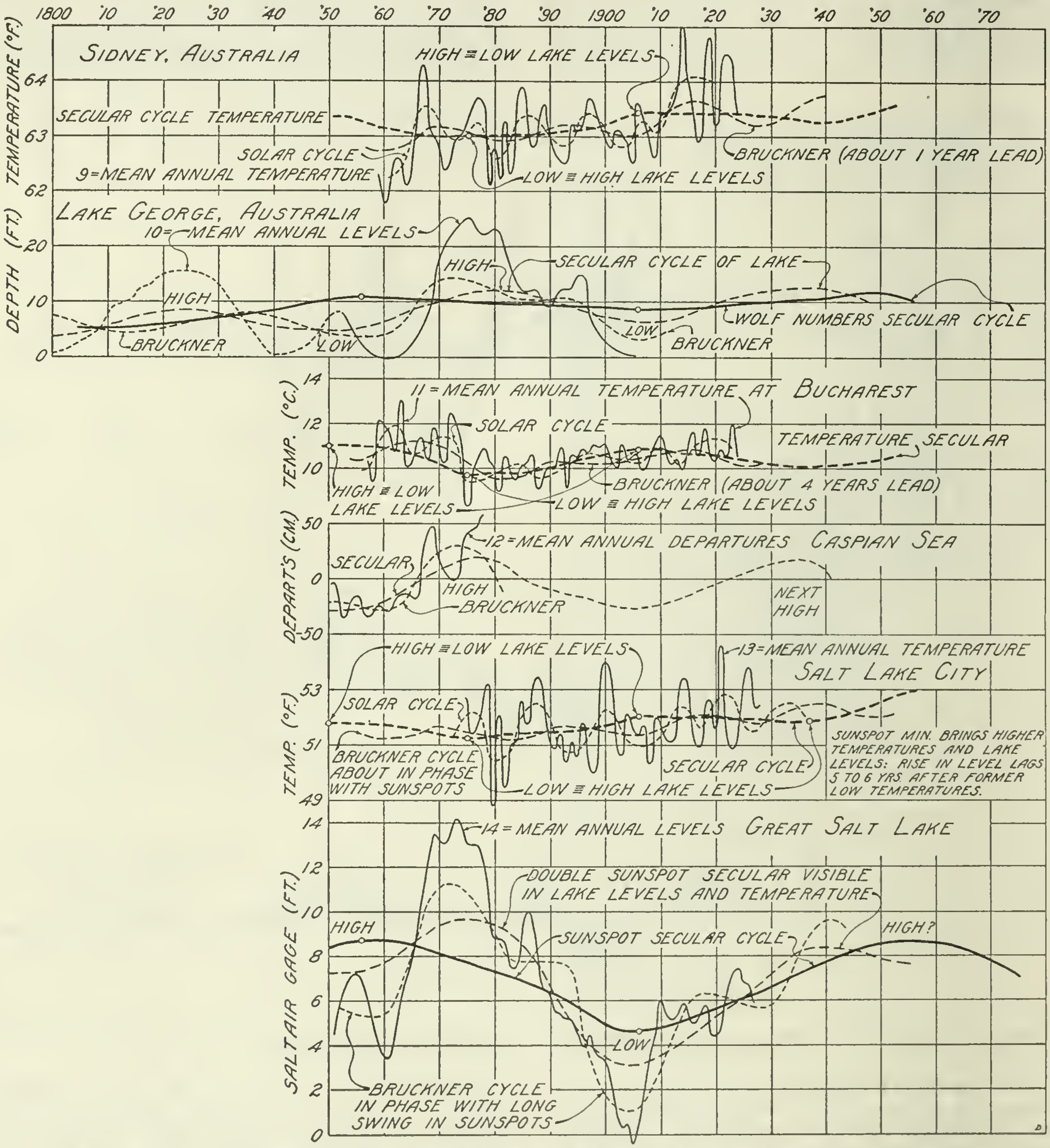

FIGURE 5.—Mean annual temperature, Sydney and Bucharest and levels of Lake George, Australia, Caspian Sea, and Great Salt Lake, Utah

Inasmuch as Streiff (2) has pointed out the correlation between Wolf numbers and the Brückner cycle, these cycles detected in lake levels, are no longer of uncertain periodicity. While the amplitudes of the cycles in rainfall and temperature are mostly of very small order their effect in lake levels is apparently greatly magnified, as already pointed out (4). The apparent results of

promptly followed or accompanied by increased rainfall (see Brückner's data, fig. 3, or any other rainfall and temperature graphs for a certain place one wishes to make); the results being that the lake levels rise very much faster than they would had the evaporation continued at the same rate as in above normal temperature trends. The same applies to run-off. A simple analogy

fits the case clearly—rainfall and temperature, in their causative effect in raising and lowering lake levels, are analogous to the motor and brakes of an automobile, the former tends to raise or drive forward, the latter tends to retard the action. It appears that at the time of increased rainfall, the "brakes" are taken off.

Knowing what to look for, in the matter of cycles, it is now comparatively easy to detect them in a record of levels, and the probable future extensions of the larger tions, with very hot summers. The return of this lake to its former size and depth is a matter of grave concern to the citizens of that part of the State. Beach marks of former greatly higher levels are in evidence around the lake. It is quite likely that this lake will again refill, but level records are insufficient to set up with certainty the cycles. However, at the eastern end of the lake, the desiccation has continued to the extent that petrified, or alkaline coated stumps of trees are now visible.

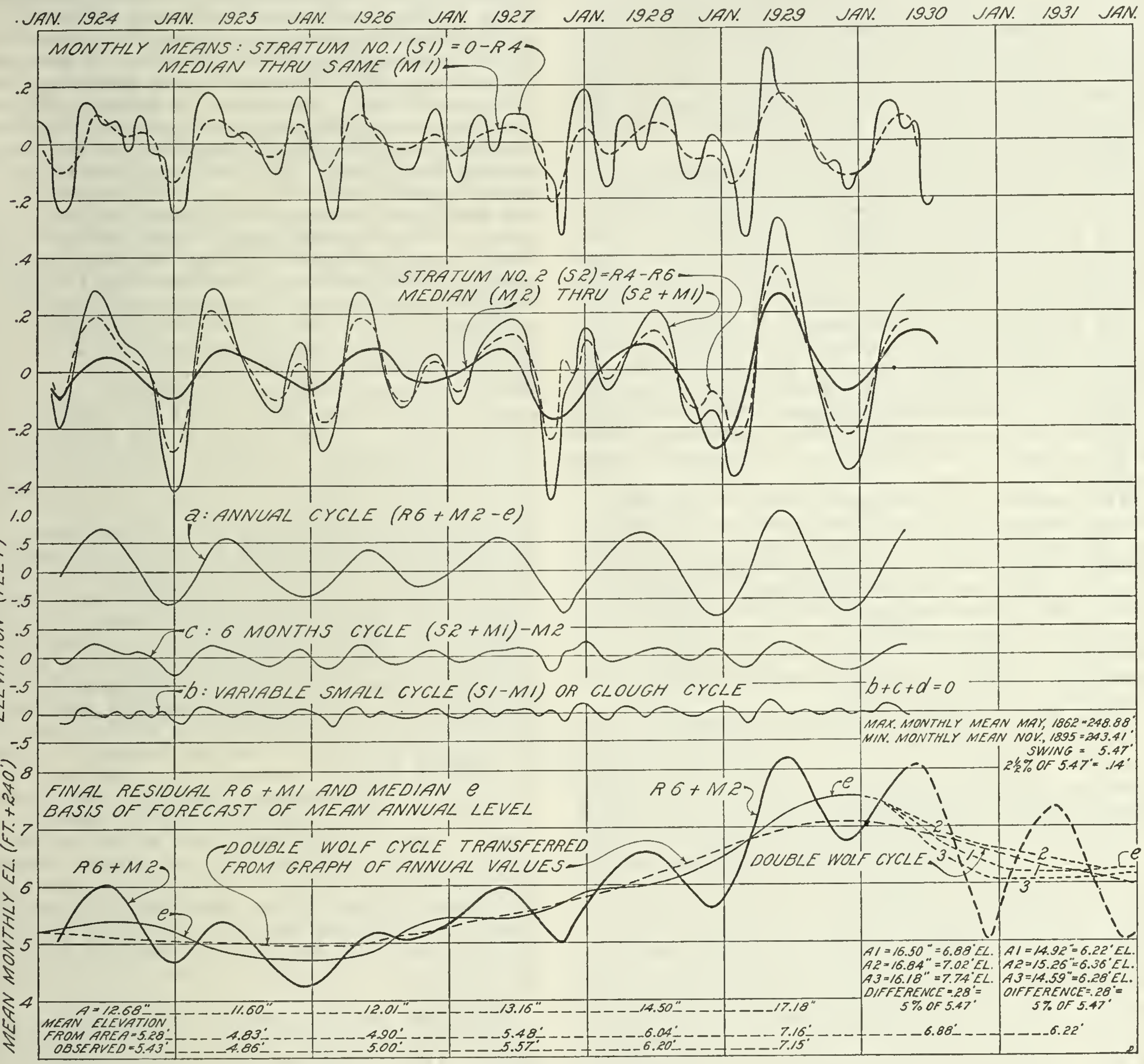

FIGURE 6.—Lake Ontario analysis

swing cycles, predicated on the probable recurrence of the Wolf numbers maxima and minima, and the trend of their secular cycle, enables us to set up a general picture of the future probable levels.

Devils Lake, N. Dak., is a no-outlet lake, and in 1867 was of considerable size and depth (111 square miles area). It has been steadily reduced in area and depth until in 1928 it has fallen 25 feet. The rainfall in this region varies from about 10.5 to 25.5 inches per year. This region is also subject to great temperature oscilla- This indicates, beyond a doubt, that in former times, this lake was drier even than it is now, and stayed so, long enough for a good sized tree to grow.

In the foregoing, we have pointed out, that the Brückner cycle in rainfall and temperature records follows, or is in step with, a similar cycle in Wolf numbers, and that as a HIGH or LOW point in the secular swing of the Wolf numbers necessarily entails two HIGHS of the Brückner cycle, one before and one after the secular cycle turning points, there results a "double" secular cycle, which is

considerably mangified in lake levels; achieved apparently by the teamwork of rainfall and temperature, acting together at the temperature secular LOW, and against each other at the temperature secular HIGH.

The combined study of rainfall and temperature of a certain district will yield a good deal of information as to probable lake levels therein, even though no long continuous record of such is available, and each district must be studied separately. We are greatly indebted to Brückner for his work and discussions, pioneer in its nature. This investigation was undertaken after a hint from Mr. Strieff, who wrote in a personal letter to the writer, that he was convinced there was a double secular cycle in lake levels, after studying levels of several long records. Seeking for a cause, temperature records were investigated, as well as a search through Brückner's book, with the results as given herein.

For a lake with outflow, we take Lake Ontario. The mean annual levels are plotted in curve No. 1, Figure 4, with a greatly exaggerated vertical scale. Curve No. 2 is the double Wolf cycle, derived from No. 1. Curve No. 3 is the fourth residual of curve No. 2, and is approximately the solar cycle. Through the centers of the loops of this solar cycle is passed the curve No. 4, which is the Brückner cycle, and through the Brückner cycle loops are passed curve No. 5, the lake levels or double secular cycle; and finally through the swings of this last is passed the curve No. 6, the secular cycle of the Wolf numbers. Comparing the Brückner cycle in this graph with that of the sun spots, Figure 2, it will be noted that in Lake Ontario, the Brückner seems to lead by about eight years.

The continuous records of monthly mean levels of Ontario began in 1860, and there is also available, data as to high water in 1838 and low water in 1819. Two curves of temperature are given for comparison, Figure 4, one, curve No. 7 for Toronto, and curve No. 8 for Detroit, Mich. The Detroit temperature is given only to show the similarity of the secular cycles, to show the probable temperature trends of Toronto further back than its record goes, and also to point out the approximate phase coincidence of their solar cycles.

For a lake belonging in this class, comparing curves 1 with 7, it is apparent that temperature secular cycle has only a general effect, and that the temperature, Brückner, and solar cycles have a very pronounced effect, disregarding any consideration of rainfall. In the graph of curve No. 1, the extensions into the future of curves 3, 4, 5, and 6 are tentative only, predicated upon probable sun-spot numbers for the ensuing period, and the trend of the Wolf secular thereof. We do know, however, that the Wolf numbers secular cycle is rising toward a HIGH, and that this HIGH is likely to occur around 1950. Also, we can feel sure that there will be a HIGH of the double (lake) secular cycle prior to this HIGH of the Wolf secular. Also, the direction of trend of the Brückner cycle in the lake levels (curve No. 4) in the immediate future is somewhere near to the truth. If any reliance can be placed upon past behavior repeating itself, in a fashion, under similar conditions of cause, it would seem as though the mean annual levels of Lake Ontario were due for an oscillating reduction (first, high, then lower, but generally downward) for a few years, then an upward trend until about 1940; the values from 1930 to 1950 being perhaps a little less than for the 1870 to 1890 period.

With reference to levels prior to 1860, there is a record of high water in 1838, at 8.98 + 240 feet. The mean level for the year seems to average, in these records, about 1.25 feet less than the maximum level for the year, so that the probable mean annual level for Ontario in 1838 was about 7.73 + 240 feet. For the year 1819 there is a record of low water for Michigan, but not for Ontario. Lake Michigan was 6.6 feet lower in 1819 (584.3 − 577.7) than in 1838. This probably means the difference between the recorded maximum of 1838 and recorded minimum of 1819—not mean monthly levels. These greatly varying levels when plotted in the graph of curve No. 1, Figure 4, seem to check, with the cycle shown.

This lake, like the no-outlet lakes discussed, is rising and falling in step with certain well-known climatic cycles. Streiff (3) gives a method of analyzing river run-off data, which I have applied to lake levels here. I have taken the mean monthly levels, and treated them exactly like river run-off data. The results are shown in Figure 6. Four successive additions of consecutive monthly means were first made, R1, R2, R3, and R4. R4 was restored to scale by dividing by 16 and to phase by shifting results upward 2 months. R4, thus restored to scale and phase, was now subtracted from the original monthly means, giving Stratum No. 1 (=S1), shown in curve No. 1, at top of Figure 6. Next, two more reductions were made, taking every other value of R4 for addition, finally securing thus R6. After restoring to this scale by dividing by 4 and to phase by shifting upward 2 months, R6 was subtracted from R4, giving Stratum No. 2 (=S2), plotted in curve No. 2, just below curve No. 1. A median line is now drawn through S1, following the general contours of S2 (curve No. 2), and the ordinate values of this median, M1, are taken off and added to curve No. 2 values, giving curve No. 3. Next a median line M2 is drawn through curve No. 3, following the general swings of R6, (which may be tentatively plotted below for comparison temporarily) and the ordinate values of M2 are taken off and added to R6, giving curve No. 4. The median line "e" passed through the curve No. 4 is the final residual, whose mean ordinate for the 12 calendar months of the year, is approximately equal to the mean annual level. Subtracting M1 from S1 gives the (b) or Clough cycle; M2 from (S2 + M1) gives the (c), or 6 months' cycle; and "e" from (R6 + M2) gives the A = (a) or annual cycle. The algebraic sum, for a year, of these three cycles is equal to zero; also the algebraic sum of the three cycles, a, b, and c, and the residual "e," equals the original monthly means graph. Residual "e" is superimposed on the double Wolf cycle, also shown in curve No. 4. This is the same cycle as curve No. 2 in Figure 4, and its approximate path in the next ensuing year is shown. Residual "e" can also be extended a year or so into the future. The latest monthly mean levels data on hand at the time this study was completed, was for September, 1930. Note that the vertical scale in curve No. 4, Figure 6, is in feet from 4 to 8 feet, and that these values are to be added to the base elevation, 240 feet.

The highest recorded mean monthly level was in May, 1862 = 248.88; and the lowest was in November, 1895 = 243.41. This is total swing of 5.47 feet. Two and one-half per cent of this amount is equal to 0.14 feet. In extending residual "e" through to the end of 1930, I have shown three possible extensions; No. 1 is the base, for forecast values, No. 2 will give 2½ per cent greater elevation and No. 3 will give 2½ per cent less elevation, than for the base value. Residual "e" is shown plotted only from 1924 to date. The area, A, under the residual, and between January to January ordinates and zero below, is shown for each year; also the equivalent mean level, and the observed level. For all practical purposes, the computed and the observed values are the same.

For the year 1930, the extension No. 1, gives a mean elevation of 6.88 feet, for the year, or 240+6.88=246.88 feet. Extensions Nos. 2 and 3 are given simply to show that considerable error may be made in extending this residual "e," and yet influence the results only 5 per cent of the total maximum swing from highest to lowest mean monthly levels recorded. In order to forecast as closely as possible, one should secure the data to the end of the calendar year; as it is, the extension for the year 1931 indicates that the mean annual level will be about 6.22+240=246.22 feet, still lower than for 1930.

The accuracy of these forecasts depends a great deal in predetermining the path of the double Wolf cycle. In this record of lake levels, these double Wolf cycles do not emerge as perfectly as one could wish. If they were perfect, they would consistently appear in a certain relation to the sun spot maxima and minima. As it is, we can only tentatively extend them. If is self-evident, from a close inspection of curves Nos. 1 and 2, Figure 4, that the double Wolf cycle has reached its peak at 1929, and will trend downward to about 1932–33.

The same remarks apply to lakes with outflow, relative to investigating rainfall and temperature as for no-outlet lakes. It is most important to discover the lag of rainfall behind the temperature oscillations, and if possible the lag of the levels behind that of the rainfall. With lakes having data similar to Lake Ontario, one does not need necessarily to make these rainfall and temperature studies, only as indicated herein, to discover the epochs of the secular swings.

In his chapter headed "The Significance of Climatic Oscillations in Theory and Practise," Brückner says (p. 274).

Our climatic oscillations can also be modified due to different land conditions. Especially in arid districts, where there is little water, the hydrographic conditions alter greatly, in that they follow the oscillations of the rainfall. A map made during a dry period, will often present an entirely different picture, than if it were made during a wet period. Lakes vanish in dry periods and return in wet; viz, Lake George in Australia, which in 1820 and 1876 was an important lake 20 to 30 kilometers long, and an insignificant lake only in 1850. It was 10 kilometers wide and 5 to 8 meters deep, and in the dry periods, dwindled away completely down to the ground, so that grass grew in its basin. Likewise the neighboring lakes, Cowal and Bathurst, became depleted in the dry periods, and refilled in the wet periods. From a full consideration of these facts, it is clear that lakes Cowal and George behave somewhat like Lake Zurich. Very similar also is lake Hamun-Sumpf of Persia, although this does not completely dry up. Great, also, are the oscillations of Great Salt Lake, whose area changed from its minimum in 1850 to its maximum in 1870 a full 17 per cent, like that of Lake di Fucino, whose area decreased 19.2 per cent from 1816 to 1835. Relatively small, although very definite, are the larger oscillations of the Caspian Sea.

In an attempt to utilize Brückner's ideas, in the past, so many anomalies developed that his work has lain in obscurity. Brückner, himself, was unable to discover any correlation between his cycle and the sun spots. Great credit, therefore, should be given Streiff (2) for his discovery of this relationship, and why its existence had hithertofore escaped us; for until he made it, there was nothing to tie to—our climatic cycle was of a greatly varying period, and no one knew when it would change or end. With out present knowledge, we can turn back to Brückner's book, and use the information it contains to great advantage. Brückner calls attentoin in the extract given above to the difference that may exist in a map made in the dry period as against one made in the wet period. The last major climatic oscillation peak was about 1856, or 74 years ago. Practically all of our important railroad and public highway work has been done since that time. Most of our park systems driveways, and roads of all types for auto travel, in the various States, have been completed within the past 30 years, namely, beginning at the very lowest point of our climatic swing (1900 to 1910). There is every reason to believe, therefore, as the next 20 years comes on apace, we will witness considerable damage to work done during this past régime of weather.

(1) Klimaschankungen seit 1700, by Ed. Brückner, Vienna, 1890. This was also published as Heft II in Penck's Band IV, Geographische Abhandlungen.
(2) A. Streiff in Monthly Weather Review, July, 1926, Washington, D. C.
(3) A. Streiff in Monthly Weather Review, March, 1928, Washington, D. C.
(4) A. Streiff in Monthly Weather Review, October, 1929, Washington, D. C.
(5) United States Geological Survey data.

WEATHER AND CORN YIELDS

By W. A. Mattice

[Weather Bureau, Washington, April, 1931]

Corn is one of the most widely grown crops of the United States; practically every State grows some corn, whether for grain or silage. The heaviest production is concentrated in nine States, comprising what is known as the "Corn Belt"; here is found about 60 per cent of the Nation's acreage and in 1925 this region produced 70 per cent of the total production. Figure 1 shows the area under consideration. The States outlined contain the Corn Belt proper, but the sections of heavy production do not include the entire region shown, as it is confined to the central parts of the Ohio Valley States, most of Iowa and Missouri, southeastern Minnesota and South Dakota, and eastern Kansas and Nebraska. The figures shown in the State boundaries are the percentages of the total crop area that is planted to corn in each State.

The weather data used in this study were obtained from the State Section Summaries and the original records of observations on file at the central office of the Weather Bureau. The precipitation and mean temperature data are State averages for all meteorological stations, but the maximum temperatures, percentage of possible sunshine, and p. m. relative humidity were obtained by averaging data of selected first-order stations.

As is usual in a study of this type, covering a relatively long period of years, it was necessary to adjust the records available to the several State boundaries, but every effort was made to keep the data representative and comparable. The yield data were obtained from the United States Department of Agriculture reports.

The method developed by Kincer (2) was applied to the several State data, using five weather elements covering the period April 1 to September 30, inclusive. In order to conserve space, and also as the method is familiar to most of the readers of this publication, the various data used in computation of the bases are omitted and only the final computed yields are given. By the expression "bases" is to be understood the computed yields used as a weather index for subsequent calculations. That expression is used for brevity and convenience in discussion. Table 1 shows the actual corn yields in bushels per acre and Table 2 the computed bases; the averages for the

section are also given. The subsequent tabulation gives the data used in computation of the final bases and the equations derived therefrom.

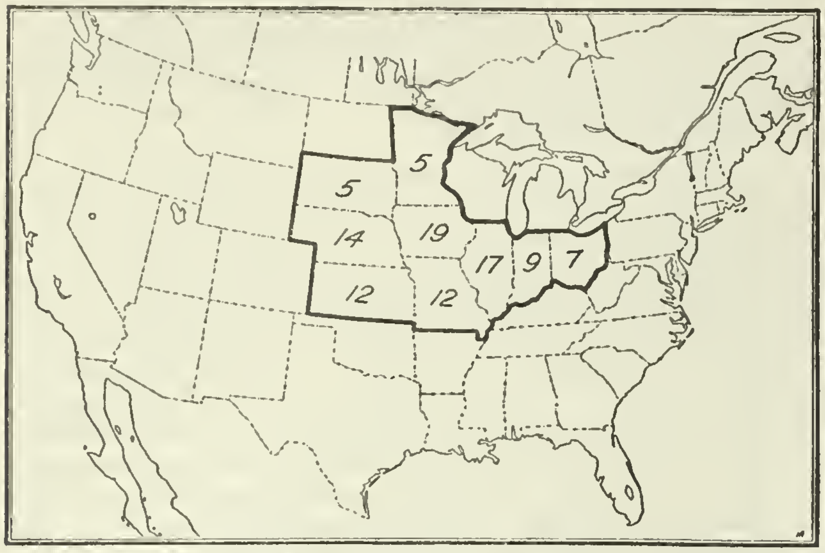

FIGURE 1.—The Corn Belt States. Region outlined shows the area of heaviest production. This area in 1925 grew 59 per cent of the total corn crop of the United States. Figures within State boundaries indicate per cent of total acreage planted to corn in the respective States

A word of explanation is necessary at this point. The weather variables for Ohio were so numerous that the computation of a straight multiple equation was avoided, the data being first combined in groups of three variables

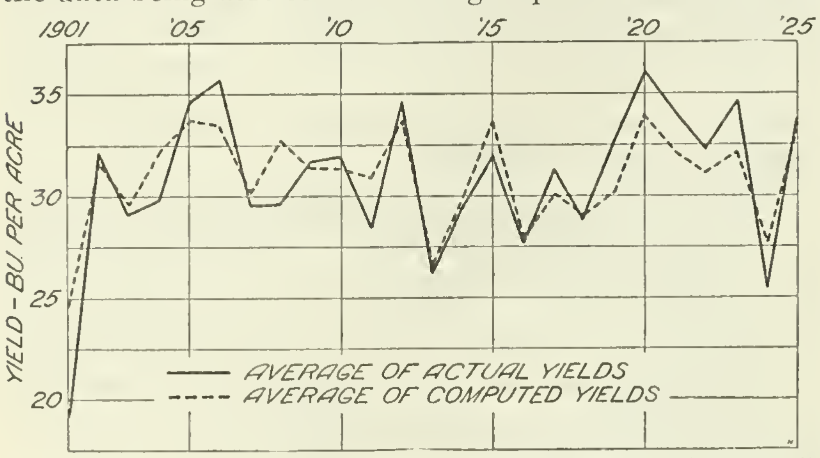

FIGURE 2.—Computed and actual yields of corn, bushels per acre, for the Corn Belt. Arithmetic average of individual State bases

and a final equation computed from them. Thus, this State has three preliminary equations, the results being combined in the final, or fourth, expression.

TABLE 1.—*Yields of corn, bushels per acre*

Years	Ohio	Indiana	Illinois	Minnesota	Iowa	Missouri	South Dakota	Nebraska	Kansas	Average
1901	26.1	19.8	21.4	26.3	25.0	10.1	21.0	14.1	7.8	19.1
1902	38.0	37.9	38.7	22.8	32.0	39.0	18.9	32.3	29.9	32.2
1903	29.6	33.2	32.2	28.3	28.0	32.4	27.2	26.0	25.6	29.2
1904	32.5	31.5	36.5	26.9	32.6	26.2	28.1	32.8	20.9	29.8
1905	37.8	40.7	39.8	32.5	34.8	33.8	31.8	32.8	27.7	34.6
1906	42.6	39.6	36.1	33.6	39.5	32.3	33.5	34.1	28.9	35.6
1907	34.6	36.0	36.0	27.0	29.5	31.0	25.5	24.0	22.1	29.5
1908	38.5	30.3	31.6	29.0	31.7	27.0	29.7	27.0	22.0	29.6
1909	39.5	40.0	35.9	34.8	31.5	26.4	31.7	24.8	19.9	31.6
1910	36.5	39.3	39.1	32.7	36.3	33.0	25.0	25.8	19.0	31.9
1911	38.6	36.0	33.0	33.7	31.0	26.0	22.0	21.0	14.5	28.4
1912	42.8	40.3	40.0	34.5	43.0	32.0	30.6	24.0	23.0	34.5
1913	37.5	36.0	27.0	40.0	34.0	17.5	25.5	15.0	3.2	26.2
1914	39.1	33.0	29.0	35.0	38.0	22.0	26.0	24.5	18.5	29.5
1915	41.5	38.0	36.0	23.0	30.0	29.5	29.0	30.0	31.0	32.0
1916	31.5	34.0	29.5	33.5	36.5	19.5	28.5	26.0	10.0	27.7
1917	38.0	36.0	38.0	30.0	37.0	35.0	28.0	27.0	13.0	31.3
1918	36.0	33.0	35.5	40.0	36.0	20.0	34.0	17.7	7.1	28.8
1919	43.0	37.0	36.0	40.0	41.6	27.0	28.5	26.2	15.2	32.6
1920	43.4	40.5	34.6	37.5	46.0	32.0	30.0	33.8	26.5	37.0
1921	41.0	36.0	34.0	41.0	42.0	30.0	32.0	28.0	22.2	34.0
1922	39.0	37.0	35.5	33.0	45.0	28.5	28.5	25.0	19.3	32.3
1923	41.0	38.5	37.5	36.0	40.5	30.0	34.5	33.0	21.7	34.7
1924	26.0	25.6	33.0	27.0	28.0	24.0	21.3	22.0	21.7	25.4
1925	48.0	43.5	42.0	36.0	43.9	29.5	17.5	26.0	16.6	33.7
Mean	37.7	35.7	34.7	32.6	35.7	27.7	27.5	26.1	19.5	30.8
σ	5.21	5.00	4.44	5.14	5.73	6.16	4.52	5.35	7.12	3.68

TABLE 2.—*Computed yields of corn, bushels per acre*

Years	Ohio	Indiana	Illinois	Minnesota	Iowa	Missouri	South Dakota	Nebraska	Kansas	Average
1901	34.0	26.1	26.9	32.9	35.5	16.2	23.6	15.9	9.5	24.5
1902	34.8	36.0	42.6	26.2	30.2	31.1	25.3	29.9	28.4	31.6
1903	30.9	34.9	34.3	26.8	31.4	30.4	27.6	21.2	28.0	29.5
1904	35.8	32.6	37.7	25.2	38.7	33.3	26.5	31.6	28.3	32.2
1905	37.9	37.3	40.1	34.6	33.5	31.3	33.2	30.1	25.1	33.7
1906	46.3	37.4	31.5	28.9	40.5	29.9	29.9	29.6	26.4	33.4
1907	34.6	36.9	35.2	29.7	31.4	30.2	27.6	23.5	21.6	30.1
1908	41.0	34.3	34.8	31.4	33.7	30.8	31.2	30.3	26.4	32.7
1909	37.3	38.4	34.4	35.3	34.9	26.3	28.9	26.3	19.8	31.3
1910	36.1	41.1	35.5	35.8	32.1	31.8	21.4	25.0	23.3	31.3
1911	37.5	37.6	34.0	37.0	39.4	27.9	22.3	23.8	18.0	30.8
1912	44.8	41.8	39.4	30.8	39.8	29.5	28.9	27.2	20.2	33.6
1913	38.0	35.4	30.2	37.9	34.3	18.4	24.0	15.4	3.2	26.3
1914	37.4	33.5	28.5	34.3	36.7	24.6	27.3	25.7	18.4	29.6
1915	42.5	41.7	35.1	21.3	28.6	38.6	30.1	33.4	31.5	33.6
1916	29.8	31.8	29.5	31.1	35.8	22.3	29.8	24.3	12.0	27.4
1917	34.0	33.0	37.6	31.4	36.8	31.4	26.8	25.9	12.7	30.0
1918	36.4	33.6	36.7	34.4	30.4	21.6	33.4	24.0	9.8	28.9
1919	38.7	30.7	31.7	37.0	40.3	26.4	27.6	24.1	15.3	30.2
1920	38.9	38.1	33.1	36.1	40.4	32.0	34.1	31.7	20.8	33.9
1921	41.1	36.5	35.7	37.9	38.6	26.4	28.1	22.6	21.6	32.1
1922	38.3	37.6	32.5	35.5	41.0	27.5	28.5	21.1	19.1	31.2
1923	39.5	34.2	35.9	34.3	34.8	28.6	27.9	34.1	19.3	32.1
1924	30.0	28.0	34.2	29.1	28.4	31.3	21.9	27.5	18.5	27.7
1925	46.8	43.6	38.9	35.9	43.1	27.5	23.4	24.1	16.1	33.3
Mean	37.7	35.7	34.6	32.4	35.6	28.2	27.6	25.9	19.7	30.8
σ	4.38	4.08	3.64	4.27	4.12	4.74	3.43	4.69	6.69	2.42
Sxy	2.81	2.76	2.52	2.93	4.06	3.90	2.94	3.09	2.76	------
rx	+.84	+.83	+.82	+.82	+.71	+.78	+.76	+.82	+.92	+.89

Ohio.—Equations and variables used.

$$X_1=0.781A-0.489M+1.032B-50.335 \quad (1)$$

$$X_2=-0.595E+0.401K+0.552C+17.755 \quad (2)$$

$$X_3=0.259G+1.744D+0.347F-12.827 \quad (3)$$

$$\overline{X}=0.589X_1+0.413X_2+0.297X_3-11.290 \quad (4)$$

A = Mean temperature, September.
B = Mean temperature, June.
C = Mean maximum temperature, April.
D = Total precipitation, July.
E = P. m. relative humidity, June.
F = Mean maximum temperatures, September.
G = Percentage of possible sunshine, June.
K = P. m. relative humidity, August.
M = Percentage of possible sunshine, July.

Indiana.—Equation and variables used.

$$\overline{X}=2.646A+0.234L+0.433H+0.559D-22.990$$

A = Total precipitation, July.
L = Percentage of possible sunshine, May.
H = Mean maximum temperatures, September.
D = Total precipitation, September.

Illinois.—Equation and variables used.

$$\overline{X}=0.476A-0.412F+1.230K-0.603G-0.722E-0.438J+110.907$$

A = P. m. relative humidity, July.
F = Percentage of possible sunshine, September.
K = Total precipitation, April.
G = Mean maximum temperatures, August.
E = Total precipitation, July.
J = P. m. relative humidity, September.

Minnesota.—Equation and variables used.

$$\overline{X}=0.622A+0.526C+0.154F-0.441I-0.333M-16.187$$

A = Mean temperature, June.
C = Mean maximum temperatures, August.
F = Percentage of possible sunshine, July.
I = P. m. relative humidity, April.
M = Percentage of possible sunshine, April.

Iowa.—Equation and variables used.

$$X=0.912A+1.734D-1.122F-0.558I+0.543J+0.130L-30.656$$

A = Mean temperature, September.
D = Total precipitation, April.
F = Total precipitation, May.
I = Mean temperature June.
J = Mean maximum temperatures, May.
L = Percentage of possible sunshine, June.

Missouri.—Equation and variables used.

$$\bar{X} = -0.894B - 723C + 169.102$$

B = Mean maximum temperatures, August.
C = Mean maximum temperatures, July.

South Dakota.—Equation and variables used.

$$\bar{X} = 1.737A + 0.291B + 1.496K + 0.143F + 0.078H - 8.866$$

A = Total precipitation, May.
B = P. m. relative humidity, July.
K = Total precipitation, April.
F = Percentage of possible sunshine, May.
H = Percentage of possible sunshine, September.

Nebraska.—Equation and variables used.

$$\bar{X} = 0.638A - 0.504E - 1.191D - 3.373L + 0.593H + 0.270J + 63.808$$

A = P. m. relative humidity, August.
E = Percentage of possible sunshine, June.
D = Mean temperature, July.
L = Total precipitation, July.
H = Mean maximum temperatures, June.
J = P. m. relative humidity, July.

Kansas.—Equation and variables used.

$$\bar{X} = 0.399A + 0.430B + 0.245O + 0.177L - 45.981$$

A = P. m. relative humidity, August.
B = P. m. relative humidity, July.
O = P. m. relative humidity, May.
L = P. m. relative humidity, September.

One striking feature that is instantly apparent is the fact that every variable in Kansas is relative humidity; this item appears more important in the Plains than elsewhere. Undoubtedly, the relative humidity at the p. m. observation is a fairly good index of the weather conditions as affecting corn, at least in the Plains States. The moisture conditions are more precarious here than farther east, and anything which tends to increase evaporation, would necessarily produce its effect on crops. Evaporation and relative humidity are closely related, so the latter produces an indirect effect on yields through that relation.

The coefficients of correlation, as shown in Table 2, are all fairly high, ranging from 0.71 for Iowa to 0.92 for Kansas. Iowa has always been a rather difficult State for which to correlate corn yields and weather, so the low coefficient there was not surprising. Kansas, on the other hand, has been a favorable one for correlation purposes. One item shown in Table 2, the standard error of estimate, Sxy, needs some explanation. The value shown is derived in the same manner as standard deviation, except that the departures are computed from actual and computed yields. The standard error, compared with the standard deviation of yield, shows the value of the coefficient of correlation instantly, for if the standard error is not sufficiently smaller than the standard deviation, the coefficient is valueless. It might be added that in order to reduce the standard error to 50 per cent of the standard deviation it is necessary to have a coefficient between 0.86 and 0.87.

Figure 2 shows the actual and computed yields of corn in bushels per acre for the Corn Belt as a whole. The two sets of data were obtained by averaging the yields for the nine States. The agreement is very close, except for 1901. The coefficient of correlation between these values is 0.89, a value sufficiently high to justify the statement that yields are largely dependent on the weather, and that we have included the major items necessary.

WEIGHTED CORRELATIONS

It is realized, of course, that the method of obtaining the final computed yields for the Corn Belt as a whole, is open to question, as the method of weighting each State equally would be considered erroneous by some authorities. It was with this thought in mind that the entire ground was again covered in a different manner.

The various States appeared to lend themselves readily to a grouping by sections, as follows: The Ohio Valley, the Mississippi Valley, and the Great Plains. The Ohio Valley States were Ohio, Indiana, and Illinois. The Mississippi Valley States were originally intended to be Minnesota, Iowa, and Missouri, but in examining the coefficients it was found that Missouri did not correlate with the others, in fact, when Minnesota and Iowa had positive coefficients with a certain weather variable, Missouri was negative, etc. Therefore, it was decided to combine only Minnesota and Iowa in the Mississippi Valley and include Missouri in the Great Plains as it correlated with the latter area.

The final grouping of the Great Plains then became: South Dakota, Nebraska, Kansas, and Missouri. The disagreement of Missouri is very interesting, as it indicates that Missouri weather resembles that of the Plains more than that of the Mississippi Valley.

The weights were found by computing the per cent each State acreage was of the total for the group. Thus, the per cent of corn acreage of Ohio was obtained by dividing the acreage of corn in Ohio by the acreage of the Ohio Valley group. This percentage was obtained for each year of the 25 studied, for as the acreage varied, so the weight that should be given to an individual item should vary. The yields were weighted by multiplying each yield figure by its corresponding percentage, then obtaining the sum of the results. Thus, there was obtained a final yield figure that was weighted directly by the importance of the several States.

The selection of the variables to be used was somewhat more complex. As a preliminary step the coefficients of correlation of each State for the five weather items were entered in a table. It was then possible to pick out those months of greatest importance as the coefficients would all be of the same sign, although of various magnitudes. The selected values were then weighted in the same manner as the yields and the coefficients of correlation obtained. From this step on the method is exactly the same as before, so a detailed discussion is not necessary. The equations and variables used are given below.

The Ohio Valley.—Equation and variables used.

$$\bar{X} = 0.575A + 0.745F - 0.658E - 1.161B + 0.180H - 6.450$$

A = P. m. relative humidity, July.
B = Total precipitation, July.
E = Mean temperature, July.
F = Mean temperature, September.
H = P. m. relative humidity, September.

The Mississippi Valley.—Equation and variables used.

$$\bar{X} = 0.643A + 0.177C + 1.784D + 0.115K - 28.043$$

A = Mean temperature, September.
C = Percentage of possible sunshine, May.
D = Total precipitation, April.
K = Percentage of possible sunshine, June.

The Great Plains and Missouri.—Equation and variables used.

$$\bar{X} = 0.433A + 0.258B - 0.661C + 0.205N + 0.341O + 8.881$$

A = P. m. relative humidity, August.
B = P. m. relative humidity, July.

C = Mean maximum temperatures, July.
N = P. m. relative humidity, May.
O = Percentage of possible sunshine, July.

P. m. relative humidity is still of greatest importance in the Great Plains, but elsewhere there is a wider range of the variables.

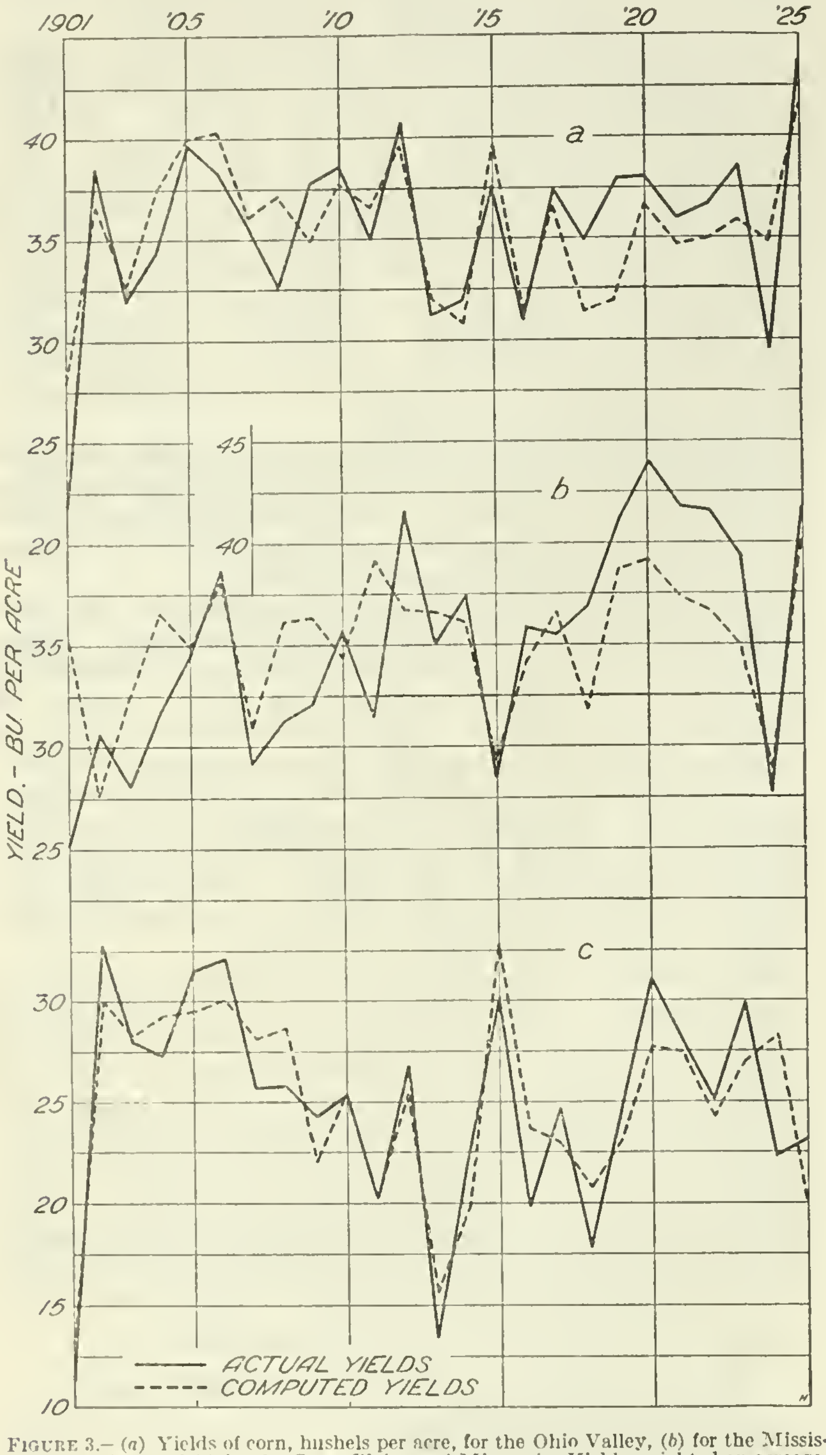

FIGURE 3.—(a) Yields of corn, bushels per acre, for the Ohio Valley, (b) for the Mississippi Valley, and (c) for the Great Plains and Missouri. Yields weighted on acreage-percentage basis

Figure 3 shows the computed and actual yields for these three divisions, "a" being that for the Ohio Valley, "b" that for the Mississippi Valley, and "c" that for the Great Plains and Missouri. The final bases and yields are also given in Table 3. The Great Plains again agrees more closely with actual yields than the others, with a coefficient of 0.88, while the Mississippi Valley coefficient was only 0.63.

TABLE 3.—*Computed and actual yields of corn for the three divisions of the Corn Belt*

Years	The Ohio Valley		The Mississippi Valley		The Great Plains and Missouri	
	Computed	Actual	Computed	Actual	Computed	Actual
1901	28.0	21.9	35.2	25.2	12.8	11.3
1902	36.6	38.4	27.7	30.7	29.9	32.6
1903	32.6	32.0	32.4	28.0	28.0	27.9
1904	37.5	34.4	36.6	31.8	29.2	27.2
1905	39.9	39.7	34.9	34.5	29.4	31.4
1906	40.3	38.3	37.7	38.7	30.0	32.0
1907	36.1	35.7	30.9	29.1	28.2	25.7
1908	37.2	32.7	36.1	31.3	28.6	25.8
1909	34.9	37.7	36.4	32.1	22.1	24.3
1910	37.7	38.6	34.4	35.7	25.4	25.4
1911	36.6	35.0	39.2	31.5	20.3	20.3
1912	39.5	40.7	36.7	41.5	25.3	26.8
1913	32.0	31.3	36.6	35.1	15.6	13.4
1914	30.8	32.0	36.1	37.4	19.9	22.4
1915	39.5	37.6	29.3	28.5	32.6	30.1
1916	31.3	31.1	34.3	35.8	23.7	19.9
1917	36.5	37.4	36.6	35.5	23.0	24.6
1918	31.4	34.9	31.8	36.9	20.8	17.8
1919	32.0	37.9	38.7	41.2	23.2	24.5
1920	36.6	38.0	39.2	44.0	27.7	31.0
1921	34.7	36.0	37.4	41.8	27.4	28.1
1922	35.0	36.7	36.7	41.6	24.3	25.2
1923	35.9	38.6	34.8	39.3	27.0	29.9
1924	34.8	29.6	28.9	27.7	28.3	22.3
1925	41.6	43.7	40.2	41.7	20.2	23.2
σ	35.6	35.6	35.2	35.1	24.9	24.9
Mean	3.32	4.31	3.25	5.21	4.68	5.30
rx	+.77		+.63		+.88	

In combining these three divisions to make a final computation for the entire area, two methods were used. First, a simple arithmetic average, and second, by weighting on an acreage-percentage basis. The acreages for the several divisions were divided by the total for the belt and the yearly percentages obtained. The coefficients of correlation were, respectively, for the weighted and unweighted values, 0.83 and 0.78. Figure 4 shows the

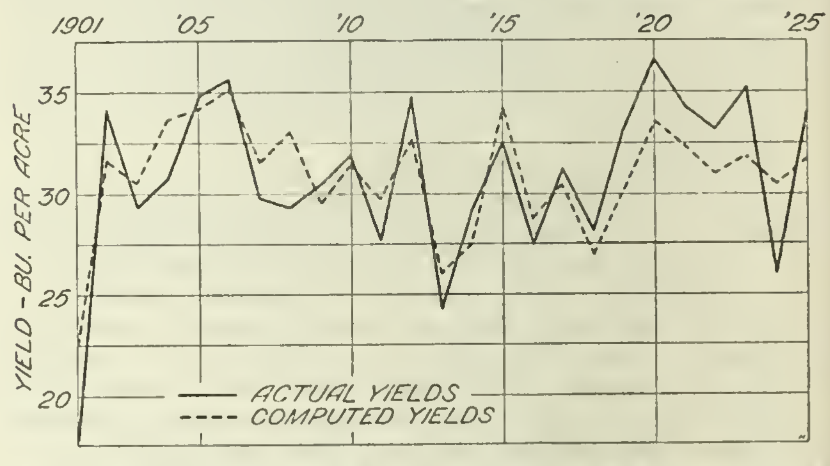

FIGURE 4.—Yields of corn, bushels per acre, for the Corn Belt. Weighted average of the three divisions

computed and actual yields for the weighted values; there is again very close agreement, except for one or two years.

In order to give the weighting method a further test, it was decided to weight the original final bases for the individual States, obtained as before indicated. The percentage of acreage in each State was computed, based on the acreage of the entire region, and these percentages applied to the final bases. The computed yields thus obtained were compared with the actual figures, also

weighted, and the final coefficient of correlation was 0.90. This small increase over the original method is very important, as there is an increased reduction of standard deviation of about 2 per cent.

The yields computed in this manner agree a little more closely in those years which were at variance before, thus making this method a little better than the other one. The actual and computed yields are shown in figure 5.

Thus, we have two methods of computing corn yields in the belt. The method of weighting seems to be of slightly more value than that of simple arithmetic averages. The weighting of individual weather items in correlating weather and corn yields does not return as high a coefficient as considering each State individually and then weighting to its proper place in the belt.

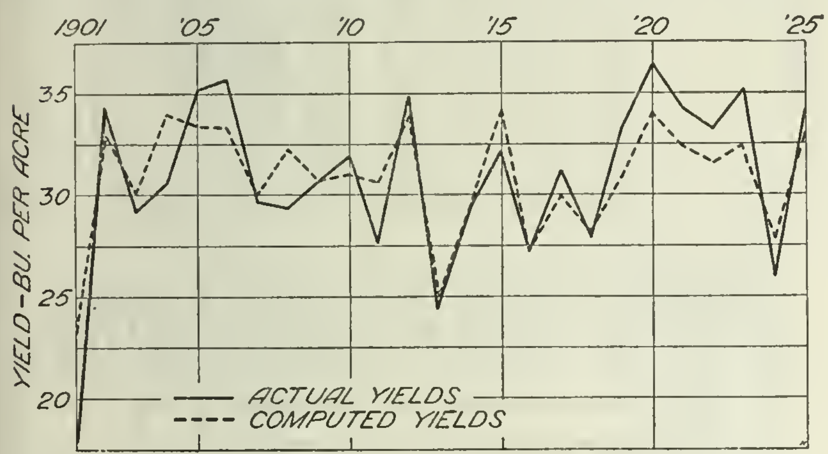

FIGURE 5.—Yields of corn, bushels per acre, for the Corn Belt. Weighted average of individual State bases

THE STATE OF IOWA

In Iowa "Corn is King." The corn crop is to this State what cotton is to the South. It follows, therefore, that any factor that affects the size of the corn crop is of vital interest not only to the State, but to the Nation. The weather is, naturally, the most important element influencing the growth of corn and this paper will attempt to show those periods of most importance.

The average corn production in Iowa for the years 1921–1925 was 426,000,000 bushels, or about 15 per cent of the average of the whole country for the same period. It will be seen, therefore, that the Iowa corn crop is of great importance, and many investigators have studied the effect of weather on the yields of corn in this State, but none in such detail as Wallace (1).

Wallace said, in part:

> In Iowa the multiple coefficient of correlation between yield and May temperature, July temperature, and August rain is disappointingly low * * * superficial examination of the evidence leads to the conclusion that the low correlation coefficient in Iowa is due to the fact that in Iowa there are some seasons and some sections when the yield is short because of the too cool weather during the greater part of the summer, whereas in other years the yield is short because of too hot weather. * * * Obviously, therefore, the method of correlation coefficients is not very well adapted to examining the effect of weather on corn yield in Iowa.

With this conclusion there was set forth a series of tables, based on correlation coefficients, from which could be computed the percentage the crop would be above or below an average determined from a line of secular trend. This was done for two counties, one in the northern and one in the central part of the State, with the main work on Polk County crops. While this method of computing yields is sometimes very satisfactory, it can not be said that it has a strict mathematical foundation, therefore it was decided to apply Kincer's method (2) to the yield and weather data of Iowa.

In a study of this type, based on average yields for a whole State, the stations chosen for the weather data must be well distributed and fairly representative of conditions over the whole section. There are, of course, periods when a complete distribution is difficult to obtain and for such cases the best data available may not completely satisfy the necessary requirements. Iowa is fairly well covered by a network of cooperative stations and the weekly precipitation data are based on the entire number, computed from the climatological records. The regular Weather Bureau stations, of course, do not fully cover the State, but for such data as sunshine, and mean and maximum temperatures they are believed to be adequate. Four stations were chosen for the temperature factor, Dubuque, Des Moines, Charles City, and Sioux City, covering fairly well the section of heaviest production.

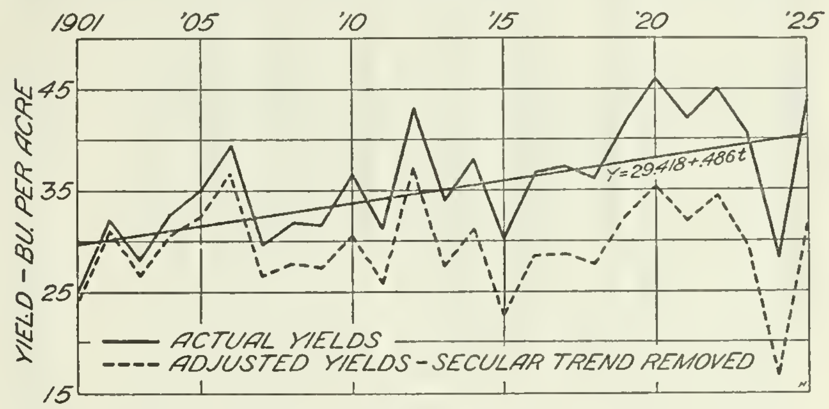

FIGURE 6.—Yields of corn, bushels per acre, for the State of Iowa. Upper solid line shows observed yields, lower broken line shows the adjusted yields after removal of secular trend. Line of secular trend is also shown

The period 1901–1925 was chosen for study as nearly complete records were available for the 25 years An extension of the time backward or forward might be effected, but records become more fragmentary in the earlier years and less ready of access in the later ones.

It was found that the secular trend of corn yields in this period increased at the rate of about 0.5 bushel per year, the complete equation being $y = 29.418 + 0.486t$, where t is the time in years. Wallace had found an annual increase of 0.25 bushel in the Iowa data from 1891 to 1919 and Reed (3) found an increase of 0.283 bushel per year in the years 1890–1926. It would seem, therefore that the period, 1901–1925 was that of greatest increase in yield. Reed's conclusions as to the upward trend are very pertinent to this study and will bear repeating:

> There is a well-defined tendency for corn in Iowa to become more and more damaged by frost before it reaches maturity. * * * This scarcely leaves a doubt that the farmers of Iowa by breeding for large yields per acre have sacrificed maturity of the crop.

The success of this practice is well demonstrated in Figure 6, which shows the yields in bushels per acre for the period under consideration as well as the yields when secular trend has been removed In order to remove the trend, which is obviously unrelated to weather influences, the equation mentioned above was applied to the observed yields. The annual increment was 0.486 bushel and this, multiplied by its proper value of t, was subtracted from the original data. This, as shown, removed the external influence of increased yields and permitted the application of Kincer's method.

The new yield figures can be considered as entirely separate from the original ones and handled as desired. The mean, standard deviation, etc., were computed for the new data as though it had no connection with the original. The operations performed in this paper are as described by Kincer and need no further explanation.

TABLE 4.—*Iowa*

Year	A	B	C	D	E	F	G	H
1901	66	1.1	57	1.3	1.4	55	62	0.9
1902	79	0.9	70	0.9	1.7	55	63	0.6
1903	78	0.4	69	1.1	0.5	46	64	1.4
1904	77	0.2	65	0.7	0.6	67	58	1.2
1905	71	0.5	60	1.1	0.6	72	65	2.6
1906	78	0.8	67	1.7	0.7	58	59	0.4
1907	66	0.6	57	1.2	2.4	33	62	0.0
1908	76	1.0	65	2.0	1.6	56	70	1.0
1909	69	0.5	61	1.0	2.3	44	64	0.2
1910	67	0.7	58	0.0	0.9	64	42	0.8
1911	80	1.0	69	0.4	0.2	67	44	0.2
1912	79	0.3	68	0.2	0.5	68	54	1.4
1913	65	0.5	57	1.0	0.7	36	55	0.6
1914	81	0.5	71	0.6	1.6	60	58	0.9
1915	65	2.3	57	1.6	0.8	28	72	0.3
1916	75	0.1	66	1.3	0.9	52	61	0.4
1917	66	0.4	55	0.6	3.4	51	54	0.1
1918	75	1.1	65	0.6	2.3	59	61	1.2
1919	69	0.1	59	0.9	2.0	58	69	0.6
1920	78	0.1	66	0.3	0.6	74	52	1.9
1921	87	0.6	76	0.5	0.3	70	55	1.1
1922	75	0.8	66	0.3	0.1	38	51	0.5
1923	73	0.3	62	0.8	1.2	61	60	1.2
1924	63	1.1	52	1.4	2.5	60	66	0.4
1925	77	0.3	64	1.4	1.7	86	59	0.1
Mean	73	0.6	63	0.9	1.3	57	59	0.8
σ	6.18	0.47	5.72	0.49	0.84	13.44	7.15	0.60
rx	+.56	−.53	+.52	−.41	−.40	+.40	−.38	+.36

Year	I	J	K	L	M	N	O
1901	0.3	55	0.6	63	71	0.5	63
1902	1.6	60	1.7	59	68	0.8	57
1903	0.8	74	3.5	59	69	0.0	61
1904	0.9	64	1.6	57	71	0.3	61
1905	2.0	63	0.2	65	77	1.8	68
1906	1.4	53	1.1	75	81	1.9	71
1907	1.0	78	2.1	42	78	1.2	66
1908	1.1	71	2.7	55	87	0.0	75
1909	2.1	76	1.4	46	77	0.4	69
1910	0.6	62	0.8	40	69	0.7	59
1911	0.6	46	1.0	83	81	0.8	71
1912	0.1	48	0.5	78	75	0.7	67
1913	1.4	55	1.6	76	79	1.0	64
1914	1.0	57	1.4	72	71	1.5	62
1915	0.6	68	3.5	57	74	0.2	66
1916	0.5	60	1.5	59	70	0.0	61
1917	0.8	74	1.8	46	72	0.5	62
1918	1.9	67	2.1	60	69	0.2	60
1919	0.3	74	0.2	30	80	3.0	70
1920	1.1	54	0.7	67	83	0.1	72
1921	1.0	56	1.0	69	75	2.4	67
1922	0.8	48	1.7	77	73	0.8	62
1923	1.5	70	0.1	45	69	2.0	58
1924	2.9	60	0.7	47	65	0.6	57
1925	0.5	52	0.1	84	73	1.0	65
Mean	1.1	62	1.3	60	74	0.9	65
σ	0.64	9.29	0.92	14.09	5.33	0.78	4.89
rx	−.36	−.35	−.35	+.34	+.33	+.33	+.31

A=Average weekly maximum temperatures for the week ending May 26.
B=Average weekly precipitation for the week ending July 28.
C=Average weekly mean temperatures for the week ending May 26.
D=Average weekly precipitation for the week ending June 23.
E=Average weekly precipitation for the week ending June 9.
F=Average weekly percentage of possible sunshine for the week ending May 26.
G=Average weekly p. m. relative humidity for the week ending June 23.
H=Average weekly precipitation for the week ending May 12.
I=Average weekly precipitation for the week ending June 30.
J=Average weekly p. m. relative humidity for the week ending June 9.
K=Average weekly precipitation for the week ending May 26.
L=Average weekly percentage of possible sunshine for the week ending June 9.
M=Average weekly maximum temperatures for the week ending Sept. 15.
N=Average weekly precipitation for the week ending Sept. 22.
O=Average weekly mean temperatures for the week ending Sept. 15.

Table 4 shows the variables used. It will be noted that precipitation data occur seven times, and maximum temperatures, mean temperatures, percentage of possible sunshine, and the p. m. relative humidity twice each. It is significant that precipitation should appear nearly half the number of times, for others have found that the amount of rainfall is very important to corn, especially at certain critical periods. The coefficients are not especially high, running down from 0.56 to 0.31, but their combinations are more important than single coefficients.

TABLE 5.—*Iowa*

Year	A_1	A_2	A_3	A_4	A_5	A_6	A_7	X'	X
1901	25.2	24.8	24.2	25.5	25.3	25.7	26.2	26.7	25.0
1902	30.2	29.0	28.9	28.4	28.3	28.1	28.3	29.3	32.0
1903	31.8	30.7	30.1	30.4	29.5	30.1	29.4	30.8	28.0
1904	32.3	31.6	31.7	31.8	31.1	31.4	31.2	33.1	32.6
1905	29.1	29.8	29.2	28.2	29.1	31.1	31.0	33.4	34.8
1906	30.2	31.8	29.8	29.4	30.4	29.9	30.4	33.3	39.5
1907	27.1	28.1	27.5	27.7	28.1	27.3	26.5	29.9	29.5
1908	28.8	31.7	29.0	29.0	28.2	28.5	28.1	32.0	31.7
1909	28.5	29.3	29.0	27.9	27.5	27.0	26.4	30.8	31.5
1910	27.1	26.2	28.3	28.9	28.7	28.7	28.7	33.6	36.3
1911	30.1	31.7	32.5	32.9	32.6	31.8	32.5	37.8	31.0
1912	32.5	32.7	33.8	34.7	34.3	34.7	35.2	41.0	43.0
1913	27.2	28.4	28.2	27.9	28.1	28.0	28.4	34.7	34.0
1914	32.4	31.7	32.1	32.0	32.5	32.4	32.5	39.3	38.0
1915	20.1	20.5	19.7	20.9	20.6	20.6	20.7	28.0	30.0
1916	32.0	31.1	30.0	30.7	29.8	29.3	29.4	37.2	36.5
1917	27.9	27.6	28.3	28.7	28.3	27.6	27.0	35.3	37.0
1918	28.1	27.2	28.0	27.2	26.6	27.2	27.0	35.7	36.0
1919	30.1	31.4	31.1	31.9	33.8	33.3	32.5	41.7	41.6
1920	33.0	34.9	35.6	35.2	34.2	35.1	35.3	45.0	46.0
1921	33.9	34.0	34.4	34.2	35.4	35.4	35.4	45.6	42.0
1922	29.3	29.2	30.4	30.7	30.5	30.1	30.8	41.5	45.0
1923	30.6	29.6	29.7	29.2	30.3	30.7	30.2	41.4	40.5
1924	21.2	22.6	22.0	20.4	20.5	20.6	21.1	32.8	28.0
1925	31.9	31.7	30.3	30.9	30.9	30.1	30.6	42.8	43.9
Mean	29.3	29.5	29.4	29.4	29.4	29.4	29.4	35.7	35.7
σ	3.06	3.29	3.45	3.50	3.60	3.63	3.65		
rx	.68	.72	.76	.77	.79	.80	.81		

A_1=Weather indices computed from A and B (Table 4).
A_2=Weather indices computed from A_1 and M (including A, B, M, Table 4).
A_3=Weather indices computed from A_2 and D (including A, B, M, D, Table 4).
A_4=Weather indices computed from A_3 and I (including A, B, M, D, I, Table 4).
A_5=Weather indices computed from A_4 and N (including A, B, M, D, I, N, Table 4).
A_6=Weather indices computed from A_5 and H (including A, B, M, D, I, N, H, Table 4).
A_7=Weather indices computed from A_6 and J (including A, B, M, D, I, N, H, J, Table 4).
X'=Final computation of yields, A_7 with secular trend inserted.
X=Yields of corn, bushels per acre, Iowa.

Table 5 shows the computed values of corn yields for each successive step in the operation. The base 1, or

FIGURE 7.—Yields of corn, bushels per acre, for the State of Iowa. The solid line represents the actual yields and the broken line shows the computed yields

A_1, was computed from A and B, columns 1 and 2, Table 1; base A_2 was computed from A_1 and M, and so on up to base A_7, which concluded the series as the base A_8 did not raise the coefficient. The coefficients of correlation of these bases with corn yields increase from 0.68 to 0.81. The final base, A_7, is not adjusted as the secular trend remains to be added. This was done in the column headed X', and as column X contains the observed yields, they are directly comparable.

Figure 7 shows the computed and actual yields of corn for the years 1901–1925. There are two striking years of crop failure noted, one being in 1915 and the other in 1924. The 1915 depression is a combination of several weather influences, which are fairly well represented by the computation equation, while that in 1924 was not so well indicated as many items entered into the unfavorable conditions prevailing that season which are not repre-

sented in the equation and could not be included, under the limitations of the present data available. The season in 1924 was very late, reaching three weeks behind the average at one time, and the fall frosts cut the corn yield to a large extent. In the other years, 1906 is a conspicuous failure of the equation, but otherwise a very good relationship was obtained.

As mentioned above, the yield in 1924 was tremendously reduced; the fall frosts ended the growing season when only 32 per cent of the crop was reported fully mature, and as the average maturity at time of frost was 88 per cent, the reduction was 56 per cent, or nearly two-thirds, of the normal. The average amount of corn fit for seed was 51 per cent, but in 1924 only 16 per cent was saved. Thus, omitting 1924 from the calculations will not upset a regular sequence of years, as the recurrence of the abnormal conditions prevailing at that time can be expected only very infrequently.

TABLE 6.—*Iowa*

Year	A	B	C	D	E	F	G	H	I	J
1901	0.3	48	55	1.1	0.6	66	55	60	0.9	57
1902	1.4	74	55	0.9	1.7	79	60	72	0.6	70
1903	0.5	60	46	0.4	3.5	78	74	66	1.4	69
1904	1.0	66	67	0.2	1.6	77	64	70	1.2	65
1905	1.3	68	72	0.5	0.2	71	63	70	2.6	60
1906	0.4	70	58	0.8	1.1	78	53	77	0.4	67
1907	0.3	61	33	0.6	2.1	66	78	65	0.0	57
1908	0.1	55	56	1.0	2.7	76	71	60	1.0	65
1909	0.4	55	44	0.5	1.4	69	76	71	0.2	61
1910	0.5	65	64	0.7	0.8	67	62	69	0.8	58
1911	0.2	55	67	1.0	1.0	80	46	64	0.2	69
1912	0.7	62	68	0.3	0.5	79	48	71	1.4	68
1913	0.4	55	36	0.5	1.6	65	55	62	0.6	57
1914	0.7	62	60	0.5	1.4	81	57	73	0.9	71
1915	0.1	60	28	2.3	3.5	65	68	64	0.3	57
1916	0.0	52	52	0.1	1.5	75	60	52	0.4	66
1917	0.4	54	51	0.4	1.8	66	74	70	0.1	55
1918	0.6	62	59	1.1	2.1	75	67	54	1.2	65
1919	0.3	54	58	0.1	0.2	69	74	68	0.6	59
1920	1.4	61	74	0.1	0.7	78	54	56	1.9	66
1921	1.2	66	70	0.6	1.0	87	56	66	1.1	76
1922	1.4	64	38	0.8	1.7	75	48	69	0.5	66
1923	0.4	53	61	0.3	0.1	73	70	75	1.2	62
1925	0.4	57	86	0.3	0.1	77	52	62	0.1	64
Mean	0.6	60	57	0.6	1.4	74	62	66	0.8	64
σ	0.43	6.21	13.70	0.47	0.93	5.92	9.48	6.32	0.61	5.35
rx	+.58	+.58	+.50	−.49	−.49	+.44	−.44	+.40	+.38	+.37

Year	K	L	M	N	O	P	Q	R	S	T
1901	99	55	0.0	1.3	61	63	1.4	1.3	0.5	86
1902	81	37	0.7	2.4	64	79	1.7	0.9	0.8	73
1903	82	78	2.9	0.2	75	62	0.5	1.1	0.0	72
1904	81	51	0.9	1.0	55	80	0.6	0.7	0.3	77
1905	88	66	1.5	0.0	52	62	0.6	1.1	1.8	79
1906	80	51	0.5	0.4	63	61	0.7	1.7	1.9	70
1907	84	72	0.9	1.0	68	72	2.4	1.2	1.2	75
1908	84	84	2.0	1.1	68	65	1.6	2.0	0.0	73
1909	85	78	1.2	0.0	58	64	2.3	1.0	0.4	74
1910	87	70	0.6	1.7	58	74	0.9	0.0	0.7	74
1911	83	70	1.2	1.4	57	78	0.2	0.4	0.8	70
1912	76	51	1.0	0.6	59	69	0.5	0.2	0.7	67
1913	87	60	0.3	1.0	72	72	0.7	1.0	1.0	76
1914	87	69	0.5	0.0	57	59	1.6	0.6	1.5	75
1915	80	78	2.0	2.5	76	87	0.8	1.6	0.2	71
1916	93	76	1.1	1.3	68	67	0.9	1.3	0.0	81
1917	86	49	1.8	0.4	59	59	3.4	0.6	0.5	74
1918	87	69	2.7	0.0	64	53	2.3	0.6	0.2	76
1919	86	52	2.0	0.7	59	64	2.0	0.9	3.0	75
1920	84	80	0.7	0.7	52	57	0.6	0.3	0.1	74
1921	89	64	1.6	0.4	61	61	0.3	0.5	2.4	78
1922	83	52	0.5	0.0	67	49	0.1	0.3	0.8	72
1923	89	40	0.9	2.0	42	77	1.2	0.8	2.0	78
1925	85	64	0.7	0.8	39	68	1.7	1.4	1.0	74
Mean	85	63	1.2	0.9	61	67	1.2	0.9	0.9	75
σ	4.57	12.88	0.73	0.73	8.78	9.00	0.82	0.49	0.80	3.86
rx	−.36	−.36	−.34	−.33	−.33	−.32	−.30	−.30	+.30	−.30

A=Average weekly precipitation for the week ending Aug. 25.
B=Average weekly p. m. relative humidity for the week ending Aug. 25.
C=Average weekly percentage of possible sunshine for the week ending May 26.
D=Average weekly precipitation for the week ending July 28.
E=Average weekly precipitation for the week ending May 26.
F=Average weekly maximum temperatures for the week ending May 26.
G=Average weekly p. m. relative humidity for the week ending June 9.
H=Average weekly p. m. relative humidity for the week ending Sept. 22.
I=Average weekly precipitation for the week ending May 12.
J=Average weekly mean temperatures for the week ending May 26.
K=Average weekly maximum temperatures for the week ending July 21.
L=Average weekly percentage of possible sunshine for the week ending Sept. 22.
M=Average weekly precipitation for the week ending June 2.
N=Average weekly precipitation for the week ending Sept. 29.
O=Average weekly p. m. relative humidity for the week ending May 26.
P=Average weekly p. m. relative humidity for the week ending Sept. 29.
Q=Average weekly precipitation for the week ending June 9.
R=Average weekly precipitation for the week ending June 23.
S=Average weekly precipitation for the week ending Sept. 22.
T=Average weekly mean temperature for the week ending July 21.

Omitting 1924, a new grouping of the variables occurs which is shown in Table 6, and the number is increased from 15 to 20. The exclusion of the abnormal year enables the weather data to fit the yield data better, as it was found in the previous calculations that the year 1924 was at variance with the remainder of the years when computing correlation coefficients. The coefficients of the new variables decrease from 0.58 to 0.30, a somewhat wider range than before, while the precipitation data occupy the same important position they did in the other grouping. Thus, it can be said that the rainfall is the dominant feature of the weather influence on corn yields, but that other influences modify it.

TABLE 7.—*Iowa*

Year	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	X''	X'	X
1901	25.5	21.9	23.4	22.3	23.4	23.8	22.6	22.9	23.1	23.7	25.0
1902	30.8	31.6	30.8	32.5	32.7	31.8	32.0	31.7	31.0	32.2	32.0
1903	28.5	29.6	27.0	27.2	26.1	26.5	26.9	26.7	25.3	27.2	28.0
1904	31.2	30.8	30.2	30.8	30.9	30.0	30.3	30.5	29.8	32.3	32.6
1905	31.6	30.5	31.5	32.2	31.8	32.0	31.6	31.9	30.6	33.7	34.8
1906	26.8	28.5	28.7	30.1	30.5	30.8	31.2	31.1	33.0	36.7	39.5
1907	27.0	27.1	26.4	26.8	27.1	26.8	27.0	26.4	26.2	30.5	29.5
1908	25.0	25.6	24.3	24.1	23.7	24.0	24.3	24.5	25.2	30.2	31.7
1909	27.8	28.2	28.1	27.4	27.4	27.6	27.6	27.3	27.3	32.9	31.5
1910	27.6	28.0	28.6	29.3	29.7	29.2	29.0	29.2	29.5	35.7	36.3
1911	25.4	27.0	27.5	26.9	27.0	26.4	26.7	27.1	28.3	35.1	31.0
1912	29.6	32.4	32.9	32.5	32.5	32.2	32.9	33.0	34.2	41.6	43.0
1913	27.8	27.6	27.4	26.8	27.5	27.2	27.1	26.5	26.2	34.3	34.0
1914	29.0	29.1	28.9	29.1	29.6	30.0	29.7	29.7	30.1	38.8	38.0
1915	21.1	22.2	20.4	21.5	21.2	20.2	21.0	20.6	21.2	30.5	30.0
1916	27.3	25.4	25.5	24.7	24.9	25.0	24.4	24.5	23.9	33.8	36.5
1917	28.1	28.5	27.9	27.1	26.7	27.3	27.2	27.1	26.7	37.2	37.0
1918	26.8	26.5	25.8	26.5	25.5	26.5	26.4	26.6	26.1	37.3	36.0
1919	28.5	28.6	29.8	28.7	28.1	28.3	28.2	28.2	28.0	39.8	41.6
1920	33.2	33.8	33.9	33.2	33.3	33.7	33.6	33.8	33.4	45.8	46.0
1921	30.8	30.0	30.2	30.8	30.4	30.7	30.2	30.5	29.3	42.3	42.0
1922	31.1	32.3	31.4	31.5	31.9	32.9	32.9	32.1	31.6	45.2	45.0
1923	28.4	27.5	29.0	27.9	28.1	27.5	27.2	27.4	26.9	41.2	40.5
1925	28.4	28.8	30.1	29.4	29.7	29.6	29.5	30.3	31.6	46.5	43.9
Mean	28.2	28.4	28.3	28.3	28.3	28.3	28.3	28.3	28.3	------	------
σ	2.52	2.83	3.00	3.09	3.13	3.18	3.20	3.23	3.29	------	------
rx	+.69	+.78	+.82	+.85	+.86	+.87	+.88	+.89	+.91	------	------

A_1 = Weather indices computed from A and D (Table 6).
A_2 = Weather indices computed from A_1 and T (including A, D, T, Table 6).
A_3 = Weather indices computed from A_2 and E (including A, D, T, E, Table 6).
A_4 = Weather indices computed from A_3 and B (including A, D, T, E, B, Table 6).
A_5 = Weather indices computed from A_4 and M (including A, D, T, E, B, M, Table 6).
A_6 = Weather indices computed from A_5 and P (including A, D, T, E, B, M, P, Table 6).
A_7 = Weather indices computed from A_6 and K (including A, D, T, E, B, M, P, K, Table 6).
A_8 = Weather indices computed from A_7 and C (including A, D, T, E, B, M, P, K, C, Table 6).
X'' = Weather indices computed from X_1, X_2, and X_3.
X' = Weather indices $-X''$ with secular trend added.
X = Yields of corn, bushels per acre, Iowa (1924 omitted).

Table 7 shows the new bases computed. There is one more base this time than before, and a new computation for X. The coefficients increase from 0.69 to 0.91, which is more satisfactory, as the increase of 10 points in the correlation coefficient at this stage means 18 per cent increase in the reduction of standard deviation (4). The bases range from A_1, computed from A and D, Table 6, to A_8 and X''.

Due to the large number of bases, embracing nine variables, it was decided to compute the final equation on a somewhat different basis than before. The nine variables, A, B, C, D, E, K, M, P, and T, were combined in groups of three as follows: A, B, and C; D, E, and K; and M, P, and T, with the usual multiple correlation method used for each group. The equation for the first group was $\overline{X_1} = 1.829A + 0.215B + 0.100C - 8.603$; that for the second, $\overline{X_2} = -2.237D - 1.978E - 0.436K + 69.471$; and that for the third, $\overline{X_3} = -2.359M - 0.170P - 0.408T + 73.121$. These three equations were then used to compute three new bases, X_1, X_2, and X_3, from which the final equation was derived. The final equation was $\overline{X} = 0.577X_1 + 0.480X_2 + 0.548X_3 - 17.183$. The computed yields derived from this equation were better in fit than

those for base A_8, due, no doubt, to a better correlation of the respective variables than would be obtained in the complicated method used before. The value of the coefficient thus obtained was 0.91, an improvement over that of base A_8 of 0.02.

This final computation was still incomplete, so the secular trend was added to make it comparable with the observed yields, as shown in column X', Table 7.

Figure 8 shows the computed and actual yields with secular trend added. It will be noted that there is a much closer fit of the data than when 1924 is included and that the year 1906, which was a bad fit before is now much better.

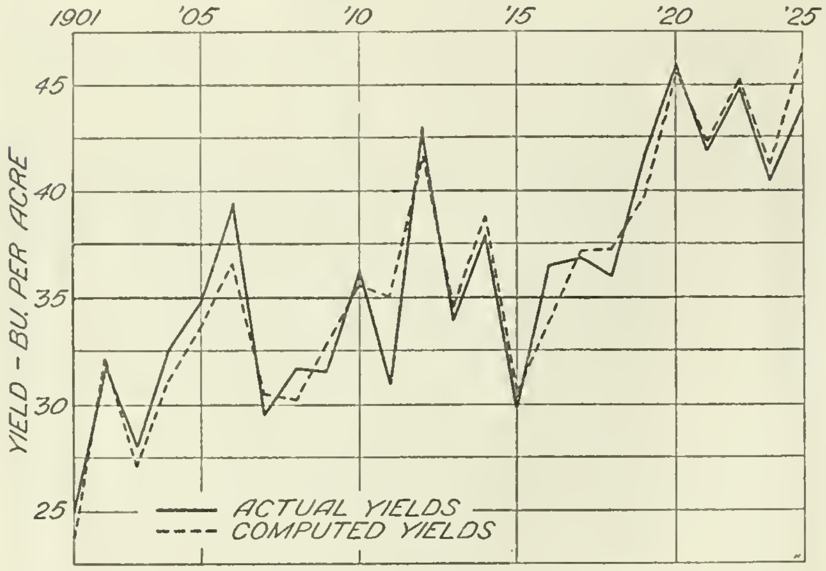

FIGURE 8.—Yields of corn, bushels per acre, for the State of Iowa. The solid line represents the actual yields and the broken line shows the computed yields. In this figure the yield data for 1924 have been omitted

No final attempt was made to forecast yields from these computations as this method of study, while it fits the data very well, is not strictly applicable for this purpose. The use of a straight-line trend in a case of this kind is limited in value. It satisfies the data under consideration, but can be of no value in forecasting, for the yields can not continue to rise indefinitely, as would be assumed from the direction of the line. Other types of curves might fit the data better, but in fitting a mathematical curve to yield data it must be remembered that extrapolation is at best very hazardous.

In computing the bases by Kincer's method, there is no effort made to reconcile the various stages of plant progression to the weather variables used and it is learned with real interest that the periods used coincide closely with the development of the corn plant in Iowa. Mr. Reed commented on this phase as follows:

I was much interested in the nine variables selected for this study. I note that they seem to have a distinct bearing on the critical planting, germination, cultivation, and pollination periods. * * * The period around May 12 is the average planting date of the bulk of the crop, and frequent rainy days, and a large total of precipitation, keeping farmers out of the fields at that time, results in a delay that is important in both yield and maturity.

The maximum temperature, the mean temperature, and the sunshine, for the week ending May 26, have a very distinct bearing on the germination. * * * The negative correlation between corn yield and rainfall in June is, I think, wholly a question of weed killing. The Iowa Experiment Station has shown that cultivation is of no value whatever except for weed killing, and that luxuriant weeds are the most serious cause of decreased yields.

It is thought that this study will serve to show the weather influences most effective in the growth of corn in Iowa. It is believed that the production of this crop will need to reach a more settled state than at present before valuable forecasting can be done from weather conditions. The farmers have developed the production of corn to procure a high yield per acre, but there is from time to time a considerable percentage spoiled by immaturity at the time of frost. Therefore it is probable that agriculture in this State will reach a settled stage when large yields per acre will be recognized as valuable, but not at the expense of full maturity, and a high-yielding corn will be developed, with a large per cent maturing before frost.

It must be admitted that, at the present stage of the development of agricultural meteorology in this country, data are usually unsatisfactory in many ways. The yield and production data are probably as satisfactory as can be obtained. The absence of organized phenological services is to be regretted as the study of crop development and its corresponding weather influences must necessarily be mere gropings in the dark until such data are available. It has been learned that a beginning in the collection of such phenological records has been made by the section director of the Weather Bureau at Des Moines, Mr. Reed, covering the whole section under his supervision, and it is earnestly hoped that nothing interferes with their continuance.

Grateful acknowledgment is made to Mr. J. B. Kincer for his kind advice and assistance in this and other papers, and to Mr. C. D. Reed for his helpful suggestions.

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RELATIONSHIP BETWEEN PRECIPITATION IN VALLEYS AND ON ADJOINING MOUNTAINS IN NORTHERN UTAH [1]

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Synopsis.—It is well known that precipitation varies widely within short distances, particularly where physical features are different. It is also well known that precipitation varies widely with elevation. Due to inaccessibility of high mountain areas few records are available to indicate the relationship of valley to mountain precipitation. In an arid region the high mountains are the source of the stream flow supplying agricultural, industrial, and municipal uses. This paper deals with variation in precipitation at different points on the valley floor and also compares the amount and distribution of precipitation on the valley floor with that above 8,000 feet.

INTRODUCTION

The development and growth of a community in an arid or semiarid region is measured by the amount and distribution of its water supply. Agriculture is dependent upon the artificial application of water for the production of crops. Communities are dependent upon water for their growth and industrial development. Hydroelectric power generation is also dependent upon the flow of streams.

The major source of waters flowing in the streams in an arid region is in the high mountains adjacent to the valleys. For many years precipitation records have been kept at valley stations. Due to the inaccessibility of the high watersheds in the winter, to the scarcity of permanent inhabitants, and to the difficulty of measuring precipitation which falls as snow, few records or precipitation are available at high elevations.

There were some 91 cooperative weather bureau stations reporting precipitation in Utah at the end of 1930. Of these 91, only 7 were at 7,000 feet elevation or above. Of the 84 below 7,000 feet elevation, 37 were below 5,000 feet elevation and 72 were below 6,000 feet elevation. In addition to the above regular cooperative stations there were 10 or 15 high elevation stations reporting only summer precipitation. Snow stakes and snow surveys furnished some data on precipitation above 8,000 feet elevation.

It has been estimated that approximately 80 per cent of the run-off of streams in Utah comes from areas above 7,000 feet elevation. This area comprises only about 20 per cent of the area of the State. It is the least known area, and yet it holds the key to the State's most valuable resource.

There is a general lack of reliable data on precipitation and other meteorological data on high watersheds in spite of the fact that these areas are the source of water supply for irrigation, domestic, and power purposes. More complete data on mountain watersheds would permit of a more complete utilization of the water resources. Such data on the high and uninhabitated watersheds can be obtained only by snow surveys at the end of the precipitation season.

PRECIPITATION

Cause of precipitation.—All waters which occur above the ocean level result from, and are renewed by, precipitation in some form. Therefore, of necessity, water supplies must vary in amount as the precipitation varies. It is true that there are many modifying factors which influence the yield from a given precipitation, but precipitation is by far the most important single factor.

Condensation of moisture out of the atmosphere may occur as fog, clouds, frost, dew, rain, snow, sleet, or hail. Of these, rain or snow are by far the most important, and the term "precipitation" ordinarily means rain or snow.

Precipitation is caused by what is known as "dynamic cooling," i. e., cooling resulting from the consumption of heat in the work of expansion of rising vapor.[3]

There are three types of precipitation: (1) Convective, (2) orographic, and (3) cyclonic. Convective precipitation is caused by the expanding air in rising vertical air currents which results in dynamic cooling and condensation. Orographic precipitation is brought about by warm air striking a mountain side and being forced to rise. As the air rises it expands, resulting in dynamic cooling and precipitation. Cyclonic precipitation results from the movement of centers of high and low air pressures. The unequal heating of the earth's surface causes the formation of these pressure centers. Warm air is rising in a low pressure area, resulting in precipitation, while cold air falling in a high pressure area results in cooler weather. These pressure centers follow each other across the country from West to East and determine largely the weather during the winter months. The storms usually enter the United States on the coast of Northern California, Oregon, or Washington, and move eastward, bending southward until the continental divide is crossed, and then bending northward again and going out through the St. Lawrence River Valley.

The distance these cyclonic storms paths are deflected southward largely determines the weather and amount of precipitation that falls in Utah during the winter months. The summer precipitation in Utah results principally from local storms. The warm air on hot summer afternoons upon striking the high mountains is forced to rise. As the air rises it expands and cools rapidly causing condensation and precipitation. This type of storm explains the spotted character of the intense summer storms, so common in Utah.

Distribution of precipitation.—The climate of Utah is divided into a distinct wet and a distinct dry season. Precipitation is light during June, July, and August and heavier during the remaining months of the year. Approximately 56 per cent of the annual precipitation at Logan occurs during the period October to March, inclusive. Cyclonic storms are the source of most of the precipitation from October to June, inclusive, while local storms furnish the precipitation from July to September, inclusive. The July–September, inclusive, precipitation is approximately 16 per cent of the annual precipitation.

In general, precipitation increases with altitude. There are a few instances, however, where it has been definitely proved that after a certain elevation has been reached precipitation decreases with increased elevation.[4]

Precipitation.—There are few precipitation records in Utah available above 7,000 feet elevation. There are some records of summer precipitation at high elevations but no records of winter precipitation.

[1] Contribution from department of irrigation and drainage engineering, Utah Agricultural Experiment Station.

[2] Associate irrigation engineer (also associate member, American Society Civil Engineers). Publication authorized by director, Feb. 6, 1931.

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In Cache Valley since 1923, 18 precipitation stations have been maintained below 5,000 feet, five precipitation stations above 8,000 feet elevation, and one at 6,250 feet elevation. At the high stations, summer precipitation was measured in standard rain gages, but winter precipitation was obtained by measuring the total accumulated snow cover at the end of the winter precipitation season. These records are brought together in this paper to point out the differences in valley and mountain precipitation during summer and winter.

PHYSICAL FEATURES OF CACHE VALLEY

Cache Valley lies in the northern part of Utah. In shape it is an irregular oval, with its long axis north and south. The maximum width, about 19.5 miles, is attained at the Utah-Idaho boundary. From this point the valley narrows at both the north and the south. About two-thirds of the valley lies in Utah and the remaining one-third in Idaho. The valley area in Utah contains approximately 450 square miles.

Cache Valley is a subsidiary valley formerly occupied by Lake Bonneville. The valley is surrounded on all sides by high, rugged, deeply furrowed mountains which are spurs of the Wasatch Range. The mountains on the east side are higher and cover a greater area than do those on the west. Mount Naomi on the east side reaches an elevation of 9,980 feet while Wellsville Peak on the west reaches an elevation of 9,450 feet. The mountains on the east side of the valley comprise the catchment basin for the streams which enter from that side. The drainage area on the east side is approximately 935 square miles, while that on the west side is only 122 square miles.

Except for Wellsville and Clarkston Peaks, a small low range of mountains on the west side separates Cache Valley from Great Salt Lake Valley. The average elevation of Cache Valley is approximately 4,400 feet, and the average elevation of the watersheds contributing to the valley is approximately 7,000 feet.

The floor of the valley is a broad, slightly undulating plain, gradually sloping up to the foothills of the near-by mountains. The foothills and lower mountain slopes are marked by numerous old lake terraces and deltas, varying in width from a few rods to more than a mile. The generally uniform valley topography is broken by Newton and Smithfield Buttes and by the large irregular fan-shaped terraces extending out from the mouths of the large canyons.

The mountains on the east side of the valley are extremely rugged, with their major axis in a north-south direction. On the west side the axis of the range is also in a north-south direction, and, except for Wellsville and Clarkston Peaks the range is low and rolling. The valley is open from the north. A low range obstructs the valley from the west.

VALLEY PRECIPITATION

In general, summer storms approach the valley from the south or southwest, while winter storms approach from the north or northwest.

Figure 1 is a map of Cache Valley south of the Utah-Idaho line, including the contributary drainage area. The hatched line shows the approximate location of the foot of the mountain slopes. Within this designated line is the valley proper. The valley precipitation stations are marked by open circles and the mountain stations by solid circles.

Precipitation on the valley floor varies widely, the heavier precipitation occurring along the foothills. Iso-

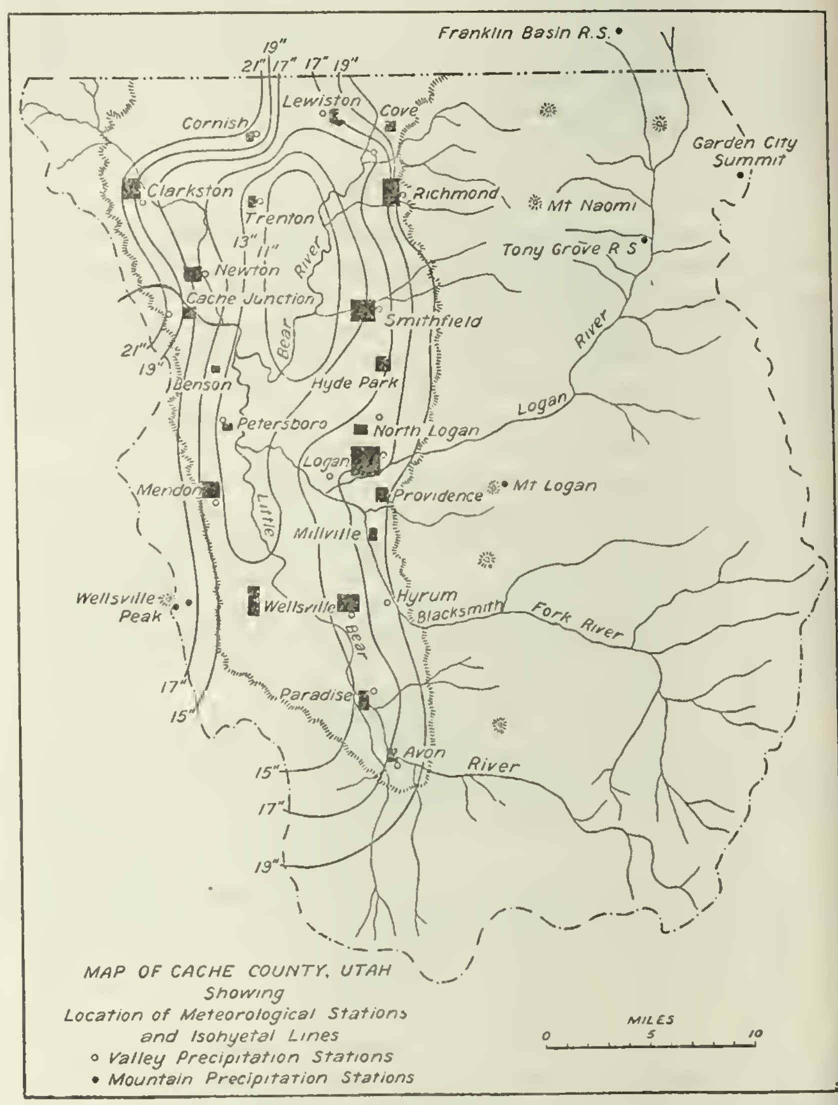

FIGURE 1

hyetal lines, indicated on Figure 1, show the general distribution of the precipitation over the valley floor. The mean annual precipitation on the valley floor varies from 11 to 21 inches. The isohyetal lines show the least annual precipitation to be over the lowest portion of the valley floor and the greatest near the foothills. The precipitation seems to increase quite uniformly with the elevation from the valley floor to the foothills. From the foothills to the top of the mountains, the precipitation increases, but the rate of increase varies widely from year to year.

TABLE 1.—*Showing mean monthly, mean seasonal, and mean annual precipitation in Cache County, Utah*

Meteorological station	January	February	March	April	May	June	July	August	September	October	November	December	April to June, inclusive	July to September, inclusive	October to March, inclusive	Mean annual
Greenville	1.44	1.34	2.00	2.62	1.43	0.94	0.44	0.63	1.06	1.34	1.17	1.91	4.99	2.13	9.20	16.32
Avon	1.56	1.86	2.70	2.09	1.44	1.43	.75	.73	1.40	1.52	2.00	1.96	4.96	2.88	11.60	19.44
Paradise	1.20	1.96	1.27	2.15	2.00	.23	1.75	.73	1.66	1.79	1.54	1.80	4.38	4.14	9.56	18.08
Hyrum U. P. & L	.93	1.75	1.91	2.50	1.93	.86	.56	.73	1.57	1.69	1.85	2.54	5.29	2.86	10.67	18.82
Hyrum, A. Fallows	.53	1.55	1.95	1.61	1.43	.79	1.26	.81	1.20	1.34	1.42	1.81	3.83	3.27	8.60	15.70
Logan sugar factory	1.90	1.46	2.35	2.17	1.46	1.03	.37	.39	1.36	1.80	1.59	1.08	4.66	2.12	10.18	16.96
Logan, U. S. A. C	1.16	1.29	1.70	1.75	1.50	1.11	.59	.56	1.60	1.23	1.32	1.36	4.36	2.75	8.06	15.17
Petersboro	.94	1.33	1.83	1.70	1.45	.85	.56	.47	1.22	1.23	1.23	1.17	4.00	2.25	7.73	13.98
Smithfield (near)	1.10	1.68	1.83	1.92	1.83	1.07	.87	.59	1.57	1.76	1.19	.74	4.82	3.03	8.30	16.15
Cache Junction	1.30	2.12	1.95	.98	2.41	.71	1.71	1.21	1.26	1.92	1.81	2.04	4.10	4.18	11.14	19.42
Newton	.92	1.43	1.60	1.46	2.07	.97	.73	.63	1.23	1.58	1.53	1.30	4.50	2.59	8.36	15.45
Trenton	.90	.40	1.45	.50	.81	1.25	.51	.66	1.23	1.64	.45	------	2.56	2.40	4.84	9.80
Clarkston	.80	.50	1.56	1.88	2.14	1.17	1.15	.71	1.54	1.87	1.98	1.10	5.19	3.40	7.81	16.40
Cornish	.75	.84	2.61	.99	1.17	1.20	1.56	1.33	.91	1.78	.90	2.12	3.36	3.80	9.00	16.16
Lewiston, 1	.96	1.09	2.03	1.21	1.60	1.49	1.05	.55	1.24	1.57	1.76	1.36	4.30	2.84	8.77	15.91
Lewiston, 2	1.37	1.36	2.00	2.02	1.78	1.53	.86	.69	1.65	1.54	2.02	1.15	5.33	3.20	9.44	17.97
Richmond, 1	.77	2.15	1.67	1.97	1.72	.96	.94	.84	1.64	1.17	1.99	1.78	4.65	3.42	9.53	17.60
Richmond, 2	1.28	1.21	2.30	1.99	1.54	1.01	.77	.73	1.54	1.55	1.63	1.73	4.54	3.04	9.70	17.28

Table 1 gives the mean monthly, mean seasonal, and mean annual precipitation at each of the 18 valley stations. It will be noted that the maximum annual precipitation occurred at Avon, a foothill station, and the minimum at Trenton, a station in the bottom of the valley. Every month shows a variation between stations, but the widest variations seems to occur during June, July, and August.

The average annual precipitation for 18 stations is approximately 8.5 per cent greater than that recorded at the United States Weather Bureau station at Logan. The average valley precipitation at the 18 stations from April to June, inclusive, equals 4.43 inches, or 27 per cent of the average annual precipitation. The average precipitation July to September, inclusive, equals 3.02 inches, or 18.3 per cent. This relatively high spring and summer precipitation accounts largely for the successful dry farms on the foothills surrounding Cache Valley.

MOUNTAIN PRECIPITATION

Summer precipitation.—Cyclonic storms are the source of most of the precipitation in Cache Valley; these storms occur with the greatest frequency during the winter and early spring. The local storms furnish most of the summer precipitation. These storms occur irregularly and are extremely spotted in intensity and total amount. They apparently contribute little to the stream flow but are important in the production of range vegetation and dry-farm crops.

In 1924 several rain gages were installed on the Logan watershed at points above 8,000 feet elevation to determine the amount of summer precipitation. These gages were set up as soon as the temperatures would permit in the spring and were taken down in the fall when the snow started to accumulate on the ground. A comparison of the record at these mountain stations with the corresponding record at the United States Weather Bureau station at Logan reveals some interesting relationships. The record at the mountain stations is compared with the record for the corresponding days at the valley station. Table 2 shows the stations compared, the elevation of each station, the period of record, and the precipitation at each station in inches. Only two stations were in operation in 1924. Franklin Basin station was not started until September 1, 1924, and, therefore, is not strictly comparable. The precipitation at 9,000 feet elevation for that year (1924) was only 9 per cent greater than the valley precipitation during the period from June 27 to September 18, inclusive. At Franklin Basin (elevation, 8,200 feet) less than one-half as much rain fell as at the Logan station (elevation, 4,780 feet) during the period from September 1 to October 31, inclusive.

During the summer of 1925 the precipitation above 8,000 feet elevation was constantly higher than in the valley. At Franklin Basin it was over three times as much, and at Wellsville Peak (elevation, 8,300 feet) it was nearly twice as much. The average of all mountain stations shows the valley precipitation to be only 54.8 per cent of the mountain precipitation. This record shows the spotted character of the mountain precipitation.

Conditions were entirely different during the summer of 1926. The valley precipitation exceeded the mountain precipitation at Mount Logan and Wellsville Peak (upper), while it was less than the mountain precipitation at Wellsville Peak (lower) and Franklin Basin. The valley precipitation for 1926 averaged 104.3 per cent of the mountain precipitation. The record for 1926 also shows the spotted character of the mountain precipitation.

TABLE 2.—*Comparison of precipitation on high watershed with that of valley, U. S. A. C., Logan*

No.	Elevation	Station	Year 1924 period	Precipitation	Valley precipitation (U. S. A. C., Logan)	Year 1925 period	Precipitation	Valley precipitation (Logan)
1	6,250	Tony Grove R.S	------	------	------	7/19–10/16	3.10	4.03
2	9,000	Mount Logan	6/27–9/18	1.33	1.22	7/16–10/21	6.25	4.03
3	8,200	Franklin Basin	9/1–10/31	1.22	2.76	5/15–10/3	19.85	6.40
4	9,400	Wellsville Peak	------	------	------	7/20– 9/25	5.35	3.50
5	8,300	do	------	------	------	5/25– 9/25	11.03	6.00
6	4,778	U. S. A. C., Logan	5/1 – 9/30	2.49	2.49	5/1 – 9/30	7.20	7.20
7	7,600	Summit G. C	------	------	------	------	------	------

No.	Elevation	Station	Year 1926 period	Precipitation	Valley precipitation (Logan)	Year 1927 period	Precipitation	Valley precipitation (Logan)
1	6,250	Tony Grove R.S	------	------	------	6/1 –10/4	4.74	3.99
2	9,000	Mount Logan	5/27–10/30	3.95	5.23	6/28–10/15	5.17	3.80
3	8,200	Franklin Basin	4/10– 8/1	5.00	4.15	------	------	------
4	9,400	Wellsville Peak	6/1 –10/16	4.13	5.12	6/21–10/11	2.72	3.80
5	8,300	do	6/1 –10/16	6.53	5.12	6/21–10/11	3.94	3.80
6	4,778	U. S. A. C., Logan	5/1 – 9/30	7.03	7.03	5/1 – 9/30	6.45	6.45
7	7,600	Summit G. C	------	------	------	7/2 –10/4	5.15	3.61

TABLE 2.—*Comparison of precipitation on high watershed with that of valley, U. S. A. C., Logan*—Continued

No.	Elevation	Station	Year 1928 period	Precipitation	Valley precipitation (Logan)	Year 1929 period	Precipitation	Valley precipitation (Logan)
1	6,250	Tony Grove R.S.				7/10– 9/24	3.05	3.35
2	9,000	Mount Logan	6/1 –10/29	2.33	3.00	6/1 –10/18	5.40	5.93
3	8,200	Franklin Basin				7/10– 9/24	2.67	3.35
4	9,400	Wellsville Peak	6/1 – 9/15	.80	1.88	6/27–10/12	4.60	4.47
5	8,300	do	6/1 – 9/15	2.40	1.88	6/27–10/12	4.00	4.47
6	4,778	U. S. A. C., Logan	5/1 – 9/30	3.35	3.35	5/1 – 9/30	5.22	5.22
7	7,600	Summit G. C				6/13– 9/24	3.95	4.76

No.	Elevation	Station	Year 1930 period	Precipitation	Valley precipitation (Logan)
1	6,250	Tony Grove R.S.	6/7 –10/7	6.48	5.89
2	9,000	Mount Logan	6/22– 9/27	5.55	4.90
3	8,200	Franklin Basin	6/15–10/7	5.79	5.89
4	9,400	Wellsville Peak	6/7 – 9/28	8.50	5.30
5	8,300	do	6/7 – 9/28	7.73	5.30
6	4,778	U. S. A. C., Logan	5/1 – 9/30	8.45	8.45
7	7,600	Summit G. C	6/7 – 9/9	4.58	3.82

NOTE.—An oil film was used in the mountain gages to prevent evaporation. The gage was emptied near the first of each month.

In 1927 the mountain precipitation was spotted and the valley precipitation was only 95 per cent of the average mountain precipitation. The mountain precipitation was spotted in 1928, but during this season the valley precipitation exceeded the average of the mountain stations.

Precipitation on the high areas during the summer of 1929 was extremely spotted. At every station except Wellsville Peak (upper) the valley precipitation exceeded that on the mountains. The valley precipitation for 1929 was 113 per cent of the average on the mountains.

The season of 1930, which was marked by several torrential storms during the months of July and August, shows a more uniform distribution of precipitation and a heavier total than any of the previous years of record, except for 1925. The mountain precipitation for the summer of 1930 was considerably heavier than the valley precipitation, the latter being only 81 per cent of the average mountain precipitation.

Although only records for seven years are available, it is quite evident that (1) there is no fixed relationship between the valley and the mountain precipitation and (2) that the mountain precipitation is extremely spotted in character. These records show that the mountain precipitation during the summer season does not greatly exceed the valley precipitation; in fact, during some years the precipitation in the valley exceeds that on the mountains. Valley precipitation stations in this regard are not good indicators of precipitation on high-mountain watersheds during the summer. Due to the spotted character of summer precipitation on mountain watersheds, a large number of precipitation stations are necessary to obtain an average record of precipitation for any given area.

Winter precipitation.—Precipitation and temperature records at Logan and observations made on the Logan River watershed show that at elevations above 8,000 feet most of the precipitation occurs as snow after November 1, and that it accumulates from that date until after the following April 1, when the melting season usually starts. Based on the assumption that any precipitation which occurs on the watershed above 8,000 feet elevation after November 1 accumulates on the ground, a measurement of the water content of the snow cover at the end of the precipitation season and before melting begins should give approximately the total precipitation occurring between these dates.

On the Logan River watershed snow surveys have been made for seven years on three courses. These courses are all above 8,000 feet elevation and are about 15 miles apart. They have proved to be representative of the snow cover conditions above 8,000 feet over the entire area.

To make a comparison between the winter precipitation on high watersheds and valley precipitation, the valley precipitation at Logan was computed for the period, November 1 to the date of the annual snow survey. The total precipitation for this period was then compared with the water content of the snow cover on the date of the survey.

Table 3 gives the precipitation at Logan (elevation 4,780 feet) and the average water equivalent of the snow cover for the three courses above 8,000 feet elevation. The snow cover measurements represent the mean of 106 annual observations taken 100 feet apart at fixed points so that the snow cover was measured in exactly the same way each year. A comparison of precipitation, caught in a standard rain gage with accumulated snow cover, is subject to some errors due to evaporation of snow and also due to snow on the ground prior to November 1 or to melting of snow after November 1. Field observations at the beginning of the accumulation season and of the soil under the snow at the time of the snow survey apparently indicates the error from these two to be slight.

TABLE 3.—*Comparison of winter precipitation above 8,000 feet and below 5,000 feet, Logan River watershed*

Year	Period	Precipitation at Logan (inches), elevation, 4,780	Water equivalent in inches of snow cover accumulated during period given				Mountain precipitation in percentage of valley precipitation
			Franklin Basin, elevation, 8,200	Tony Grove Lake, elevation, 8,300	Mount Logan, elevation, 9,000	Mean	
1923–24	Nov. 1–Apr. 6	4.69	25.1	31.8	25.8	27.6	590
1924–25	do	7.79	28.3	35.5	32.1	31.96	410
1925–26	Nov. 1–Apr. 8	8.42	18.4	21.9	22.0	20.76	226
1926–27	Nov. 1–Apr. 6	9.53	33.8	43.5	40.8	39.30	413
1927–28	Nov. 1–Apr. 5	6.23	31.7	34.9	31.6	32.70	524
1928–29	Nov. 1–Apr. 3	6.79	31.1	36.5	35.0	34.20	503
1929–30	Nov. 1–Mar. 30	6.54	26.8	31.5	25.9	28.06	507
7-year mean		7.14	27.88	33.65	30.45	30.65	430

The few records available show that evaporation from snow cover between November 1 and April 1 is slight. The record for the period from 1923–24 to 1929–30, inclusive, shows that the average precipitation above 8,000 feet was 4.3 times the precipitation for the same period at the United States Weather Bureau station at Logan. The winter precipitation above 8,000 feet varied from 2.3 times the valley precipitation during the extremely low-water year in 1926 to 5.9 times during 1923–24.

There seems to be no relationship between the valley and mountain precipitation. The maximum valley precipitation came the same year as the maximum mountain precipitation; the second highest valley precipitation (9.53 inches against 8.42 inches) came during the same year as did the minimum mountain precipitation. Figure 2 shows the poor correlation between valley and mountain winter precipitation in northern Utah.

The minimum discharge of Logan River from 1923–24 to 1929–30, inclusive, occurred in 1926. This was year of minimum precipitation above 8,000 feet elevation; it was also a year of above-normal valley precipitation. The maximum discharge occurred in 1927, which was a year of maximum precipitation both in the valley and on the mountains. The average annual discharge of Logan River is 221,645 acre-feet, or a uniform depth over the watershed of 19 inches. This is more by 2.5 inches than the annual precipitation at Logan, a valley station. On many Utah watersheds the run-off depth is greater than the valley precipitation on these watersheds.

Year	Period	Precip. at Logan Elev 4780	Mountain Precip Above 8000 Feet Elevation	Valley Precip. in Percentage of Mountain Precip.
1923-24	Nov 1-Apr 6	4.69	27.6	17.0
1924-25	Nov 1-Apr 6	7.79	31.9	24.4
1925-26	Nov 1-Apr 8	8.42	20.7	40.6
1926-27	Nov. 1-Apr. 6	9.53	39.3	24.2
1927-28	Nov. 1-Apr. 5	6.23	32.7	19.4
1928-29	Nov. 1-Apr. 3	6.79	34.2	20.2
1929-30	Nov. 1-Apr. 1	6.54	28.1	23.2

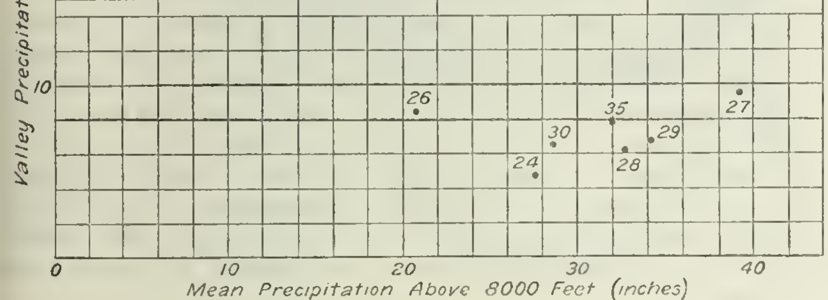

FIGURE 2

The record cited in Figure 2 shows little, if any, relationship between valley and mountain precipitation in northern Utah. This means that precipitation occurring in the valley is a poor index of the precipitation on the high watersheds or of the water-supply to be derived therefrom.

Figure 3 shows the winter valley precipitation and the winter mountain precipitation plotted against the run-off for April to September, inclusive. These curves show a poor relationship between valley precipitation and run-off. The relationship between winter mountain precipitation and run-off is much closer. Although the available record of winter precipitation on high watersheds is short, the winter precipitation as measured by annual snow surveys apparently is a good index of the water supply to be expected from such watersheds.

SUMMARY

1. Precipitation on the valley floor of Cache Valley varies widely, increasing with elevation from the bottom of the valley floor to the foothills.

2. The average spring and summer precipitation for the 18 valley stations equaled approximately 45 per cent of the total annual precipitation.

3. The summer precipitation at the valley stations is spotted, while the winter precipitation is more uniform.

4. Summer precipitation above 8,000 feet is extremely spotted.

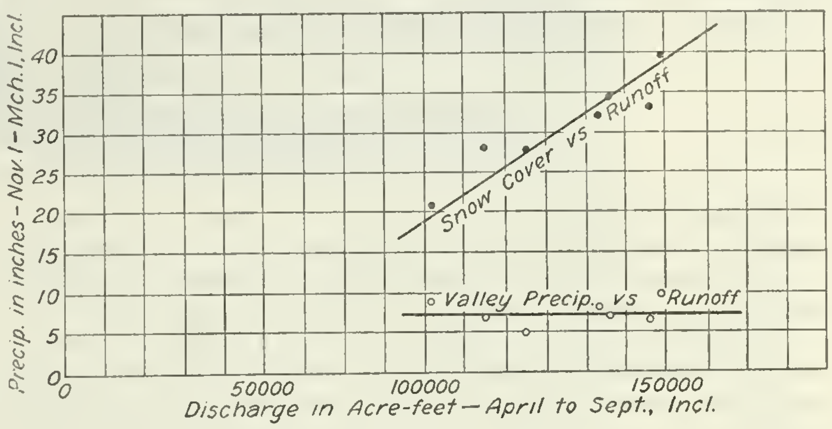

FIGURE 3

5. There seems to be no fixed relationship between the valley and mountain precipitation during the summer season.

6. Winter precipitation on high mountain watersheds is measured by snow surveys. It is quite uniform over wide areas.

7. The water equivalent of the accumulated snow cover on high watersheds is several times the valley precipitation during the period of accumulation.

8. Existing records indicate that during the winter season for northern Utah watersheds there is no relationship between valley and mountain precipitation.

9. Valley precipitation is a poor index of the probable water supplies and at times may be misleading.

10. Mountain precipitation measured above 8,000 feet elevation seems to be a good index of stream flow from that area.

THE GREEN FLASH OBSERVED OCTOBER 16, 1929, AT LITTLE AMERICA BY MEMBERS OF THE BYRD ANTARCTIC EXPEDITION

By WILLIAM C. HAINES

[Weather Bureau, Washington, D. C.]

On the evening of October 16, 1929, between 8:45 p. m. and 9:20 p. m. (180 meridian time), several members of the expedition observed a very striking example of the green flash. At the time the sun was skirting the southern horizon, its disk disappearing at intervals only to reappear again a few moments later. This fluctuation was caused by the unevenness of the barrier surface which formed the line of the horizon. The irregularities in the snow surface permitted the upper limb of the sun to appear in one or more starlike points of light from adjacent notches. These points or flares of light would sometimes have a greenish color on their appearance or disappearance. The length of time during which the green flare was visible varied from a fraction of a second to several seconds, and at times it was possible to keep it in view or to make it reappear again by raising or lowering the head. Occasionally green, orange, and red flares could be seen simultaneously at different points, giving one the impression of traffic lights. When the sun sank too low to be seen from the ground, it was still visible from elevated points such as the anemometer post or radio towers. The above effect was seen at intervals during a period lasting over half an hour.

At the time of occurrence of the phenomenon the sky was seven-tenths covered with clouds, the clear portion being along the southern horizon. A few patches of alto-stratus clouds in the vicinity of the sun showed sunset colors. There was a light southerly wind (8 miles an hour) and the temperature was −24° F. at the time. Between the sun and the camp lay a depression in the barrier within which the air was often much colder and less disturbed

than over the suronnding area. Conditions seemed favorable for marked refraction, as a very shallow layer of surface air from the south underran a northerly wind all evening, which condition should have caused a marked temperature inversion.

The phenomenon was first observed by Mr. M. P. Hanson, the radio engineer, who came in and told me to go out and look at the sun, saying, "it is green." When I reached the outside it continued green. It had exactly the same appearance as an example of the green flash witnessed by the writer and others in April, 1926, between Norway and Spitzbergen, while on the Byrd Arctic Expedition, except in this case the flash lasted only for a fraction of a second.

Conditions were more favorable for its occurrence when first observed. Later the green appeared for shorter and less frequent intervals, and the orange and red flares increased in frequency.

Numerous times while on the barrier the writer looked for the green flash under quite similar conditions but failed to observe it. This fact would seem to indicate that a favorable condition of the air is necessary for its occurrence at a time when a very small part of the sun's disk is visible.

Among other members of the expedition who observed the phenomenon were Dr. Dana Coman, physician, Mr. Frank T. Davis, physicist; and Mr. Henry T. Harrison, meteorologist.

A FIELD ALBEDOMETER

By Prof. N. N. KALITIN

[L'Observatoire Géophysique Central, Leningrad, U. S. S. R., January 15, 1931]

Measurements of the albedo of the many varieties of earth surface are of interest in numerous lines of research, e. g., to meteorology, in obtaining true values of the gain and loss of radiant energy; to plant physiology, etc.

Systematic measurements of the albedo of various crops, taken at different stages of their development, have a special value for agronomical researches. For this last purpose it is necessary to have a portable apparatus allowing easy, rapid, and uninterrupted measurements.

The A. Ångström pyranometer is a very convenient apparatus for measurements of the albedo, being light and compact, but its installation proves most unhandy. The apparatus has to be fixed and leveled on a solid support (a tripod), at the end of a small rod which places it above the area to be investigated. This rod is so short that the pyranometer can be adjusted only over the edge of the area examined, e. g., field of crops. The readings of the apparatus may also be influenced by the support, and the transportation and installation of the tripod prove inconvenient and take much time. In order to eliminate these drawbacks a field albedometer, requiring neither support nor leveling, has been constructed by the author.

The design of this pyranometer is based on the adaptation of a Cardan's suspension which automatically brings the apparatus to a horizontal position. The construction of the pyranometer is as follows: In Figure 1 the receiving parts consist of 6 thin copper bands, 3 of which are coated with magnesium oxide,[1] and 3 with soot. On the back of the bands is attached a battery of 18 copper-constantan thermocouples.

The pyrheliometer is protected by a thin spherical glass cover. The casing of the pyranometer is supported from its upper part on two diametrically opposite pivots and fastened to a ring in such a manner as to allow it to rotate freely around both pivots. In turn this ring can rotate around two diametrically opposite pivots, disposed at right angles to the first two and fastened to the ends of a half ring soldered in the middle to a tube which may be put on a rod. In other words, the casing of the pyranometer is adjusted on a Cardan's suspension. The bottom of the casing being supplied with a lead weight, the receiving bands of the pyranometer are always disposed horizontally.

For the measurements of the albedo it is necessary to make the second series of readings with the receiving surfaces turned downward toward the surface to be investigated. It is sufficient, for this purpose, to turn the apparatus 180° around an imaginary axis passing through the rod. The casing of the pyranometer will be reversed, with the receiving surfaces directed downward and, having slipped 5 centimeters down along two guides (seen in the photograph), will assume a steadfast position, with receiving surfaces disposed horizontally. (See fig. 2.)

It is evident in both cases that the adjustment of the pyranometer is rapid and automatic. During observations the pyranometer is attached to a bamboo rod 3 meters long and connected by means of conductors with a galvanometer; the loop of the Zeiss galvanometer seems the most suitable in this case, being well adapted to field work. Two men, one operating the albedometer and the other taking the readings, can accomplish a very extensive piece of work during a day.

Figure 3 shows field work carried on by means of the albedometer. This apparatus also proves very convenient for measuring the albedo of water surfaces, when it is especially difficult to level the receiving surfaces.

[1] The method given by A. Ångström.

OBSERVING THE WEATHER AT MOUNT EVANS, GREENLAND

By LEONARD R. SCHNEIDER

For a person who had lived all his life in Illinois, in the heart of the Corn Belt, the weather of Greenland presented many unusual features. It will be a few of these features, arranged in a time sequence, which I wish to describe in the following.

As an introductory paragraph, it may be pointed out that two things account for the unusually large number of fair-weather days at Mount Evans. Undoubtedly the height and length of the great Sukkertoppen iceblink lying nearly 100 miles south of us was sufficient to interfere with and perhaps ward off frequent winds and storms that might otherwise come from that direction. But far more effective in the matter of bringing clear skies was the fact that the region was subject to the drying down-slope winds which prevail from off the ice cap. Being inland some 80 miles removed us from much of the wind that makes good use of the Davis Strait-Baffin Bay highway. But the camp's other dominant feature was the practically unlimited visibility, which a mountain-top position gave us.

Our first impression of Greenland weather lived up to the mental impression always created by the word "Greenland." On July 11, only two days after our arrival at Mount Evans, more than an inch of snow fell.

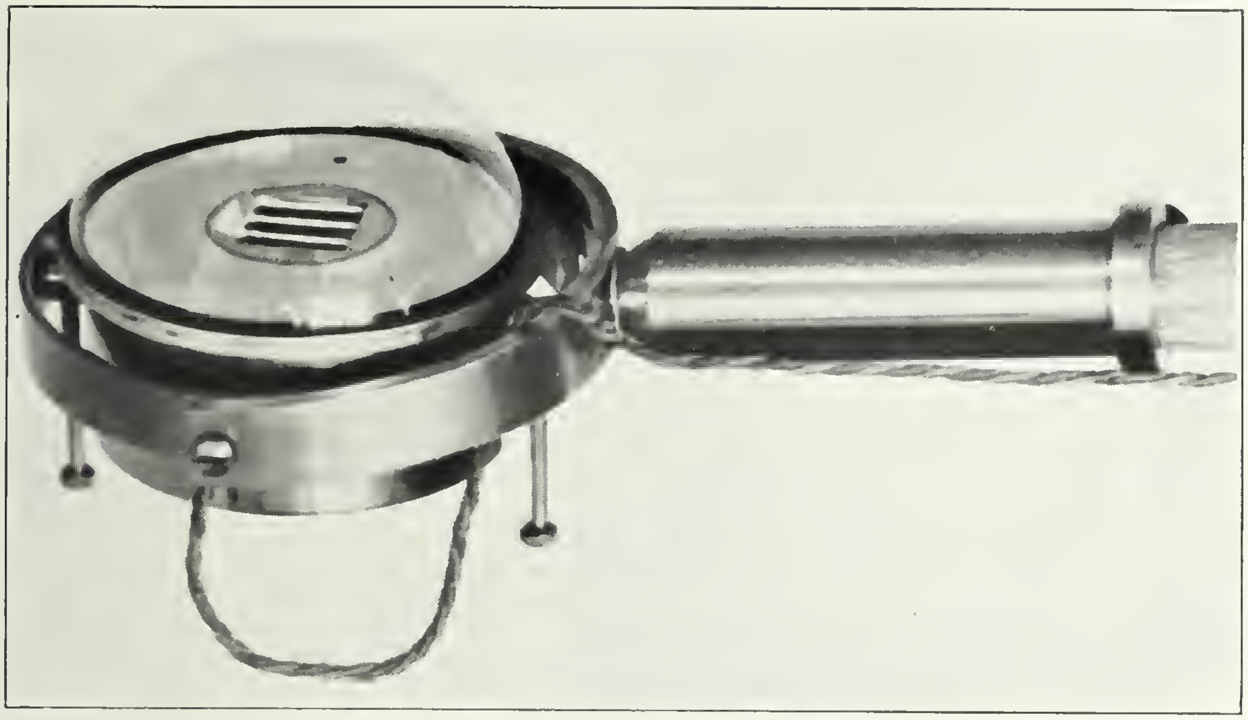

FIGURE 1.—Field albedometer, with receiving surfaces turned upward

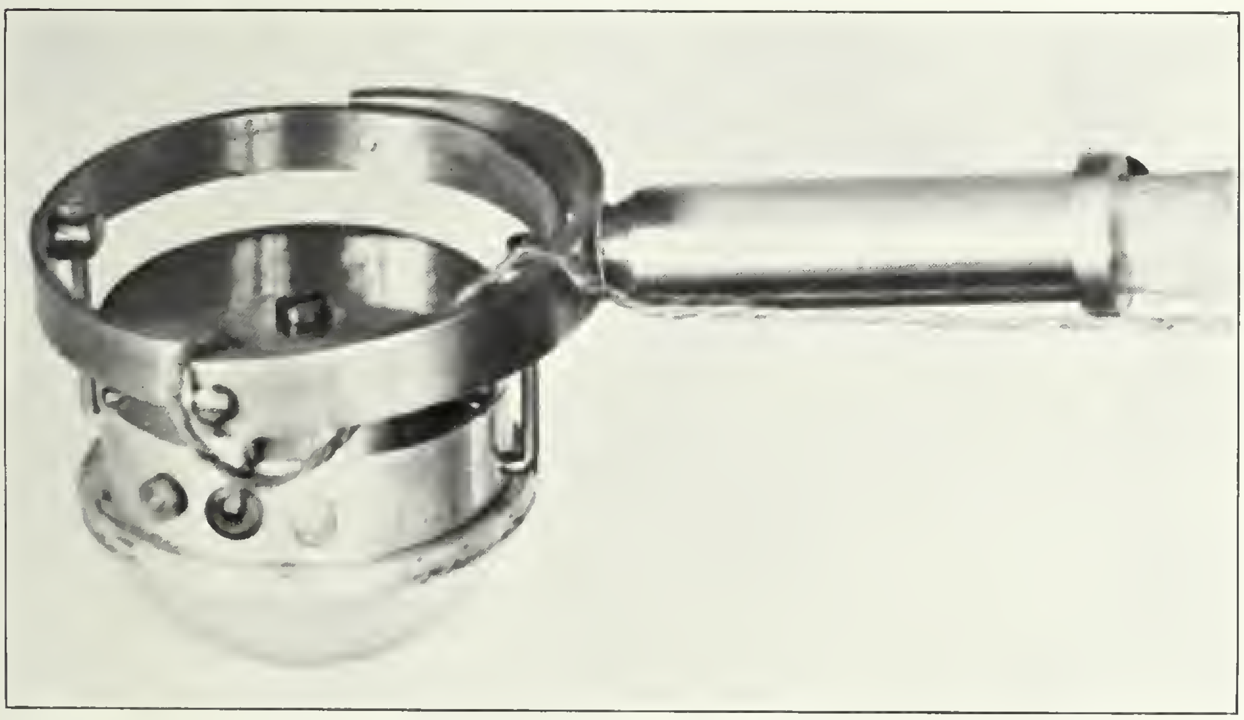

FIGURE 2.—Field albedometer, with receiving surfaces turned downward

FIGURE 3.—Observations made with the aid of the albedometer

This made the work of transferring equipment rather tedious, but the snow cover disappeared within two days and maximum temperatures in the fifties were recorded and shortly after, on July 27, the maximum for the summer, 68°, was registered. This, incidentally, was the day scheduled for the arrival of Hassell, pilot of the *Greater Rockford*. From the weather notes of that day I find these words, "perfect weather, visibility good, sky clear, wind variable and light, and highest barometer for the month."

After our disappointment caused by Hassell's first smash-up near Rockford, nature appeared to be doing all she could to lighten our spirits. At any rate, on July 23 there was a rainbow in the northwest. I believe, however, that its splendor was even surpassed by the beautiful pillar of light cast by the sun during a 10:30 p. m. sunset on July 30. The purple reflection on all the near-by lakes reached the richness of the blue of our own Crater Lake. In addition to exceedingly beautiful sunsets which some evenings seemed only to lose their beauty when the morning sun came, the next thing of note was the first appearance of the aurora borealis from 7:30 to 8:30 on the evening of August 30.

Just as we had had a fall of snow to celebrate our arrival in camp, so it was on the day of departure of Doctor Hobbs and the summer expedition, that nature provided us with a covering of white. Two days later, on the 6th of September, the three remaining Mount Evansites officially declared summer to be at an end, for a film of ice had formed on the evaporation pans. Just as a further evidence of the fact that winter was coming, I found that on September 17 at 8 a. m. my shadow measured 30 feet; on the 22d it had increased to 36 feet and on October 5 to 57 feet. These shadows kept lengthening until on December 10 the shadows and the sun disappeared from sight. It was 30 days later when we recorded the next sunrise at 11:45 a. m.

During the winter there were several unique occurrences to which I should like to call your attention. This was the winter, you remember, when the Katigat was frozen and all of northern Europe was experiencing an exceptionally cold winter, and Chicago had its greatest snowfall. In direct contrast, the west coast of Greenland had one of its mildest winters; at least records show that the January maximum was 10° higher than any January of the past 30 years. During the same month at Mount Evans, what is remarkable is that one-fourth of the days of January had hourly temperature averages above freezing.

It was during these days that we compared radiograms; those from Denmark described the ice blockade, while those from Godthavn, in Greenland, announced that the snow had disappeared and that spring flowers might be expected any time.

Unfortunately, however, these warm days were not without some discomfort, for frequently when the temperature reached the fifties the wind reached the sixties. The wind reached its maximum velocity on January 24, when the southeast wind from off the ice cap reached exactly 100 miles an hour. At this registered velocity I shall allow you to cite your own figures for what the gusts might have been. At any rate, during this blow, after some moments of anxiety, we felt relieved when the anemometer slowed up, first to the nineties, and then to the eighties and seventies, for these blasts could only tug at our house, which was securely built and streamlined against the wind. During this period of hurricane winds our well-secured radio mast was flattened against the rocks, and that gave us something to talk about, but I doubt if it equalled the remarks occasioned by the wind's wholesale disposal of our year's supply of tin cans. To have been in that barrage might have been exceedingly dangerous.

Describing the winter would not be complete without a word or two concerning the snow, and as strange as it may seem, large snowflakes were extremely rare. Most frequently the snow was as tiny pieces, fragments of flakes. It was not uncommon, however, to see ice needles. While the snowflakes were small, the frost formations were often especially well formed. Some of the frost flakes measured one-half inch in length, and on these occasions thin wires became huge ropes, and other objects changed in size accordingly.

Once I was surprised to see some whopper snowballs on the lee side of Mount Evans. Before I could photograph them, and some of them measured as much as 8 inches in diameter, the wind increased in velocity and broke these curious formations probably as quickly as they were formed. Since this was on April 2, I considered it a sort of April-fool joke.

In contrast to our Cleveland weather, I find in my notes that on April 22, the rate of melting of the snow exceeded the rate of evaporation. Only upon this occasion was there the least little mud under foot. More often, however, and at times when the down-slope winds were stronger than usual, the wind would transport for miles considerable dust that it had picked up from the the dry-land areas along the fjord.

Most of what has already been said has dealt with the winter season, and perhaps it has been so because it has been difficult to determine the date for the arrival of spring, or perhaps better, summer. Snows were frequent all during the month of April and May, and the minimum temperatures were below freezing for the most part, yet on April 23 two flies made their appearance and ducks and geese came in from the south. Finally, however, on May 15, when along the lower slopes the buttercups were showing yellow flowers almost before they had sent up their leaves, we agreed that winter must be at an end. Ice, if this be any criterion, finally disappeared from the largest of our lakes on June 3.

The following is from my notes of June 12.

> A foehn kept us busy to-day. Four balloons were sent up, one each at 9 a. m., 4 and 5 and 10:15 p. m. The last two disappeared into lenticular alto-stratus, and only the last one showed a slight backing. At 9:30 p. m., I counted 26 individual formations, but there were many others too small to count. Although during the evening the sky was practically covered with the lenticular alto-stratus, there seemed to be a level above which the formation occurred. Above that all were at more or less individual levels, with some being single and some multilayered. When the clouds came through the zenith I failed in an attempt to discover any difference in direction of movement within the cloud, that is, anything different from the general forward movement of the entire formation. When looking at the bottom of the clouds there appears to be a definite but raggy outline, and while from the side one sees a definite lens outline, some formations apparently grow down from a higher alto-stratus.

BRIEF DISCUSSION OF FOEHN CLOUDS

And now we fairly skim by an outstanding event, the midnight sun, and hurry along to the story of the schedule arrival of Parker Cramer in the Chicago Tribune plane, *Untin Bowler*. Most important in this was the fact that weather reports were coming to Mount Evans by radio three times daily from Cape Chidley, points along the west Greenland coast, Angmagssalik on the east coast, and from Iceland. The daily reports from New York were, however, much more complete, because they gave us a picture of the general weather conditions. While

Cramer was at Cape Chidley we attempted hourly communication with that station, and to the extent that fading entered in our efforts were successful in this. Cramer lost his plane at Cape Chidley, but on July 14, the day set for his arrival at Mount Evans, I find these notes, "This was the best day of the summer—clear sky, light surface winds, and moderate southwest wind aloft." A year earlier, when Hassell was expected, practically similar conditions prevailed.

In concluding this paper, I ought to relate our extreme temperatures. Winter's coldest was 41° below zero, while the maximum of the two summers was 70.1. One clear day, with a piece of black cloth, I coaxed the mercury up to 119°.

SUBSOIL MOISTURE AND CROPS FOR 1931

By HENRY C. SNYDER

[Weather Bureau Office, Denver, Colo.]

The dryness and extreme heat of 1930 were so unusual as to justify extra precautions in farming operations in 1931. In many instances wells and springs became dry that had never failed before, indicating that the subsoil water has been depleted to a dangerous point, when considering crop production for 1931. A short, dry period, such as is more or less common in the regions affected by the 1930 drought, would have more than the usual effect and cause an apparent unaccountable damage this year unless the depletion of stored moisture is considered.

It is practically certain that the drought area benefited little by hygroscopic moisture during the past winter months, and with a constant drain on capillary water for so long the outlook is very unfavorable. Water from the permanent water level may have helped some, but with our present knowledge of capillarity it seems that the subsoil could have benefited little from this source of moisture, as it is largely beyond reach. Under artificial conditions, capillarity has been known to extend 10 feet, but this required some 18 months, and the permanent water level is much deeper than this.

With regard to soil moisture, the warmth of the past winter was also detrimental, in causing more than normal evaporation. Colder weather would have been beneficial in checking evaporation and thereby holding in check the capillary water that did reach near-surface depths. The results of a cold snap in spring illustrates the point. When this occurs there is a decidedly moist layer of earth a few inches below the surface, caused by checking the capillary water and condensing the water vapor in the soil. The moist layer is usually found from 10 to 18 inches below the surface, and the moisture so stored is readily available for plant use.

Evidence of the value of a saturated subsoil was gained in an experiment in which 2 pounds of water were added to a measured amount of surface soil. It was found that after 26 hours the soil so watered had gained 3 pounds of moisture, while the soil of twice the volume immediately below had lost 1¾ pounds. This would indicate that a moist subsoil is a material aid to rainfall under normal conditions, but little or no such aid can be expected this year. Because of the dryness of the soil it is far more probable that percolation will more than offset the forces of capillarity, thus making it imperative to have adequate and timely rainfall.

During a six weeks' drought in continental Europe in 1892, fruit trees failed to mature fruit, and many trees did not recover the following year. At the same time in California the normal dry season of from four to five months did not harm the orchards, as they produced a normal crop and without the aid of irrigation; surface tillage was used to conserve moisture. The trees in Europe were shallow rooted and depended on frequent rains, while those in California were deep rooted and could stand long periods of drought. Perennials in the dry-farming sections of the United States generally draw heavily on the subsoil moisture.

The amount of water evaporated by a growing crop is so great that it is practically certain that all the moisture is not usually secured by one season's rainfall. The amount necessary to mature a crop has been variously estimated at from two hundred to eight hundred times the amount of dry matter produced. Moreover, experiments have shown that plants that have taproots use little moisture from the surface soil and these require an abundant supply from the subsoil. A crop that uses surface soil moisture for plant evaporation required heavier and more frequent rains.

CORRELATION BETWEEN WEATHER AND PUNJAB WHEAT

Volume XXV, part 4 of the memoirs of the Indian Meteorological Department (Calcutta, 1929, p. 145–161, 2 pl.), is devoted to an article on Correlation Between Weather and Crops with Special Reference to Punjab Wheat by Rao Saheb Mukund V. Unakar.

The purpose of this study is to show the results of the research being done by the Indian Meteorological Department on the problem of wheat crop prediction in the Punjab.

In this section of India, wheat is sown in October and November, while the harvesting ends by the middle of April following. The authors make several predictions during this period, one at the end of each of the months of September to March. They have worked out correlation coefficients which take into account the meteorological elements of total Punjab rainfall, Lahore maximum temperatures, and Indus River levels, and the wheat elements of area sown, gross yield, and per acre yield. The Indus River level factor is included because nearly half the area of wheat sown in the Punjab is irrigated.

Tables show correlation coefficients for the various factors involved at different months of the growing season, and charts indicate graphically the degree of accuracy attained by crop predictions based on the meteorological factors. However, no figures other than correlation coefficients were shown which would indicate the percentage error of the crop predictions. These figures, together with a reduction of the amounts of production to bushels, seem essential to a better evaluation of the work being done by the Meteorological Department. To obtain this knowledge, and also to learn the degree of accuracy shown by the official estimates, the writer has taken the figures given in Table 8 and found the following results.

Over a period of 12 years the Meteorological Department's prediction in January showed an error of 12.8 per cent from the actual yield; its error on the March prediction amounted to 11.7 per cent. That of the official estimate showed an error of 6.9 per cent, but this prediction was made at the middle of April after the

harvest. The figures just cited are obtained from averages over the whole 12-year period. The closest prediction of the Meteorological Department was within 1,000,000 bushels of the actual yield for the area studied, which totaled 126,600,000 bushels. This prediction was made in March, 1923, for the crop to be harvested in April. The closest official estimate of the Department of Agriculture was within 333,000 bushels of the actual yield, and this prediction was made in April, 1916. The greatest error made by the Meteorological Department during the 12-year period was that of their March, 1922 prediction, which was 27,500,000 bushels too low. But this error was exceeded by the official Department of Agriculture prediction made the middle of April, 1923, which was 37,400,000 bushels too high. Three of the 24 predictions made by the Meteorological Department showed a departure opposite that to the actual, while none of the 12 official Agricultural Department predictions showed such an error.

Forecasts for area sown made by the Meteorological Department and the Official Forecasting Agricultural Department for the same period of years show the following errors:

	Per cent
Average Meteorological Department error	4. 5
Average Official error	5. 2
Greatest Meteorological Department error	11. 7
Greatest Official error	8. 7
Least Meteorological Department error	. 9
Least Official error	1. 9

Two of the 12 predictions on area sown made by the Meteorological Department showed a departure opposite that of the actual, while none of the 12 official predictions showed such an error. The Meteorological Department predictions were made the last of October, while those of the Official Department came out the last of January.

These errors [while somewhat greater than those of some investigations of the United States Weather Bureau in Weather and Crop Studies of this Country] are small enough to indicate that the work of the Indian Meteorological Department is of significant value to Indian agriculture. Probably its greatest value comes through the fact that these predictions are made known so much earlier than the official estimates. Doubtless when other meteorological factors such as frost frequency, distribution of rainfall, cloud proportion, dust storms, and direction of prevailing wind are included by the Indian Meteorological Department in their corrections, their estimates will much more closely approach the actual.—*Earl B. Shaw*, Clark University.

E. KIDSON ON AVERAGE ANNUAL RAINFALL IN NEW ZEALAND FOR THE PERIOD 1891 TO 1925 [1]

The distribution of precipitation in New Zealand is affected by topography and the prevailing westerly winds in such manner that most rainfall occurs on the west sides of the islands. Rain shadows are noticeable in the central portions. The east shore has a higher precipitation than the central area on account of onshore winds. However, there is a tendency for the lowest rainfall to occur near the coast in the neighborhood of Cape Campbell. The highest precipitation is in the western highlands of both islands, over 200 inches, the lowest in the southeastern lowland of South Island, under 15 inches. The number of rainy days is practically nowhere excessive.

The accompanying five maps showing in detail the distribution of stations, relief, average number of rainy days, and mean annual rainfall of the Islands add greatly to the value of the work.—*Sigismond R. Diettrich.*

[1] Meteorological Branch, Department of Scientific and Industrial Research, Wellington, New Zealand, 1930, pp. 8, 5 maps.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1930

Three papers of meteorological interest presented at the Bristol meeting, 1930, are noted in the report of the meeting, just published.[2]

A discussion on The Meteorological Relations of Atmospherics, by R. A. Watson Watt, E. V. Appleton, R. Bureau, and M. A. Giblett, is briefly outlined (p. 293). Mr. Watt outlined the present knowledge of the subject; Mr. Bureau described the recording of the number of atmospherics per minute. Professor Appleton compared extraterrestrial with terrestrial sources, concluding that—

> The thunderstorm mechanism seems to be a more likely source than the extraterrestrial sources proposed.
>
> Attention is called to the experimental fact found by Appleton, Watt, and Herd that, for atmospherics of local origin, negative electrostatic field changes are about 1.5 times as frequent at positive, while for those of distant origin positive radiation field changes are about 1.5 times as frequent as negative. The possible significance of this is briefly discussed.

Mr. Giblett said that observations of the sources of atmospherics made at the radio research station, Slough, Bucks, at 13.00 G.M.T. daily had been plotted and studied in connection with the current synoptic charts.

The abstracts of two papers on climatic changes follow (p. 349):

Dr. C. E. P. Brooks, Climatic Changes in Historic Times.

> It appears probable that there have been during historic times certain periods when the climate of large areas differed appreciably from that of the present century. The conditions are discussed during a number of critical periods, as far as the available evidence permits:
>
> ca. 2200 B. C. Dry in Europe and western Asia. In western and central Europe the rainfall was in places only about half the present amount.
>
> 800–400 B. C. Wet and stormy, especially in central Europe.
> 0–200 A. D. Approaching present conditions.
> 500–800 A. D. Probably rather dry, especially in central Asia.
> 1200–1400 A. D. Wet and stormy in northwestern Europe.
> 1700–1750 A. D. Dry in western Europe.

Prof. A. E. Douglass, Past Changes in Climate in Relation to Settlements in the New World.

> The annual rings of trees provide a means of studying certain characters of past climates. In the southwestern parts of the United States showing an annual rainfall of 15 to 25 inches, the rings of the *Pinus ponderosa* give a very effective record of rainfall variations from year to year, increased growth accompanying increased rainfall. Long series of such ring values have been studied and variations have been found related to the 11-year sun-spot cycle.
>
> Since, in the region referred to, the climate is fairly constant over a large area, annual characters in rings may be traced over an extended forest district and thus exact dates may be carried from tree to tree. For example, we can pass from the older central part of a living tree to the outer part of an old building beam in a village 100 miles away, and then from the central part of the latter beam to the outer part of, perhaps, a log from a distant prehistoric ruin. Thus, a chronology of rings and rainfall has been carried back to 700 A. D. But this exact dating of the rings gives also the actual years of cutting the logs provided the outermost rings are still present. Thus, in return for providing material for building a climatic history the archæologists have received the building dates of some 40 prehistoric ruins. The oldest and the largest of the ruins so far dated, is Pueblo Bonito (New Mexico) whose construction period extended from 919 to 1127 A. D. The method can be successfully applied in many parts of the world but not necessarily in all.—*C. F. B.*

[2] British Association for the Advancement of Science. Report of the Ninety-eighth Meeting (Hundredth Year), Bristol, 1930, September 3-10. London, Office of the British Association, Burlington House, London, W. 1, 1931. 472 pp.

CAUSES OF FLASHY FLOODS AND MUD FLOWS IN UTAH[3]

The report of the Utah Flood Commission, of which C. L. Forsling and Reed Bailey, and R. J. Becraft of the Utah State Agricultural College are members, was forwarded to Governor Dern on December 30.

The commission concluded that the flashy floods and mud flows in Utah, although due directly to heavy torrential rains on steep slopes, were indirectly the result of sparseness of vegetation due in some cases to natural barrenness of semibarrenness of the watersheds, but in most cases to denudation by overgrazing, fire, and overcutting of timber, named in the descending order of their importance. The floods in Davis County, the worst in the State, were almost wholly the result of man-caused denudation. The floods originated on a relatively small area at the heads of the steep canyons where there has been very heavy overgrazing on privately owned land by both cattle and sheep.

The study revealed that similar rains have occurred in the past and probably will continue to occur at intervals of a few years to several decades, but there is no evidence of a similar frequency of floods. The geological evidence shows that the floods of 1923 and 1930 mark a distinct departure from the normal geological erosion that has been going on since Lake Bonneville receded to approximately the present level of Great Salt Lake, 20,000 years or more ago. The floods of 1923 and 1930 in places cut as great a depth in the Lake Bonneville deltas as had been cut in all the years since Lake Bonneville receded. Moreover, had erosion been going on since Lake Bonneville at a rate comparable to that during the recent floods there would have been huge alluvial fans several miles in length in front of the canyons, whereas these deposits are exceedingly small. Sand, gravel, and rocks, including bowlders up to 50 tons in weight, were deposited on rich farm lands, formerly lake bottom, where the original soil was a silt. Several facts relating to erosion and deposition on the shores of Lake Bonneville, formerly overlooked by geologists, were brought to light in the study.

PHYSICS OF THE EARTH—III. METEOROLOGY

Dr. J. S. Ames in 1926, as chairman of the Division of Physical Sciences of the National Research Council, was instrumental in organizing a large committee to prepare a series of bulletins on the Physics of the Earth, the purpose being "to give the reader, presumably a scientist but not a specialist on the subject, an idea of its present status together with a forward-looking summary of its outstanding problems."

Committees were formed to prepare reports on the following subjects:

The Figure of the Earth: Gravity, Deflection of the Vertical, and Isostacy; Tides, Oceans, and Earth, Variation of Latitude.

Seismology.

Terrestrial Magnetism.

The Age of the Earth.

Field Methods for Detecting Unhomogeneities in the Earth's Crust.

Internal Constitution of the Earth.

Meteorology.

Oceanography.

Volcanology.

This important project is now being realized by the appearance of the first, second, and third of the series of bulletins:

No. I treats of Volcanology.

No. II treats of the Figure of the Earth, and the present volume, No. III, the subject of this review, considers the Meteorology of the Globe. The volume consists, essentially, of a series of contributions by the members of the committee, prefaced by an introduction written by the chairman, Dr. Herbert H. Kimball, who also contributed Chapter III, Solar Radiation and its Rôle. Other committee members and their respective contributions are as follows:

Chapter I. The Atmosphere: Origin and Composition, by William J. Humphreys.

Chapter II. Meteorological Data and Meteorological Changes, by Alfred J. Henry.

Chapter III as before stated.

Chapter IV. The Meteorology of the Free Atmosphere, by Willis R. Gregg, L. T. Samuels, and W. R. Stevens.

Chapter V. Dynamic Meteorology, by Hurd C. Willitt.

Chapter VI. Physical basis of Weather Forecasting, by Richard Hanson Weightman.

The several bulletins may be purchased from the National Research Council, Constitution Avenue and Twenty-first Street, Washington, D. C.—*A. J. H.*

THE METEOROLOGY OF THE SEVENTH CRUISE OF THE "CARNEGIE[4]"

By J. H. PAUL

[Author's abstract]

An abbreviation of the usual magnetic investigations made it possible to undertake a complete meteorological program during Cruise VII of the nonmagnetic vessel *Carnegie*. In addition to the ordinary observations, a study of several special problems in atmospheric circulation over the oceans was initiated. Temperature and humidity lapse rates from quarter-deck to masthead were recorded automatically by a Hartmann and Braun electric-resistance multithermograph with three pairs of thermal elements (wet and dry) at various heights. Continuous thermograms of sea-surface temperature were obtained by a bulb-and-capillary recorder. Continuous humidity measurements were also obtained by a recording aspiration psychrometer of Negretti and Zambra manufacture for immediate use aboard and as a control on the multithermograph. These instruments were all intercompared with standard thermometers daily. A continuous record of atmospheric pressure was kept by an aneroid barograph which was daily checked by readings on standard mercurial barometers. In addition to these records, soundings of the upper air were made almost daily in the Pacific with hydrogen-inflated pilot balloons for direction and velocity of the air currents to great heights. Measurements of the rate of evaporation were carried out when conditions were favorable. Projected studies in total solar and sky radiation, although of great interest, had to be abandoned because of the difficulties encountered in working on a vessel with lofty sails and because of pressure of other work.

The great interest of meteorologists in the work of the *Carnegie* is due to the fact that she sailed in regions from which data is very scanty and was working with instruments whose accuracy is known, something one can not claim for the commercial vessels from which ocean observations are ordinarily obtained.

[3] Reprinted from Forest Service, Monthly Report of Research: December, 1930, pp. 12–13.

[4] Reprinted from Jour. Wash. Acad. Sciences, 21:46, Feb. 4, 1931.

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C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS OBTAINED DURING MARCH, 1931

By HERBERT H. KIMBALL

For a description of instruments employed and their exposures, the reader is referred to page 41 of this volume of the REVIEW.

Table 1 shows that solar radiation intensities averaged slightly above the normal intensity for March at Madison, Wis., and Lincoln, Nebr., and close to normal at Washington, D. C. But few observations were obtained at the latter station on account of unusually cloudly conditions during the month.

Table 2 shows a deficiency in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at all stations for which normal values have been established, except at Gainesville, Fla., Twin Falls, Idaho, and Fresno, Calif., which report a considerable excess.

Skylight polarization measurements were obtained at Washington on only two days. They give a mean percentage of 56, with a maximum of 60 per cent on the 25th. At Madison, a measurement made on the 28th gave a percentage of 66. These are not far from average values for March at the respective stations.

SOLAR RADIATION MEASUREMENTS FROM TULANE UNIVERSITY, NEW ORLEANS, LA.

With this month there appears in Table 2 for the first time solar radiation data from Tulane University, New Orleans, La., latitude 29° 56′ N., longitude 90° 7′ W., altitude, 40 feet above sea level. The data are furnished by Prof. Henry Laurens, department of physiology of the university.

With reference to the exposure of the pyrheliometer, Professor Laurens writes that it is on a platform 40 feet above sea level, and a sketch which he furnishes shows buildings and trees in its vicinity somewhat higher than the platform. While it does not appear that any of these objects should cut off the direct rays of the sun except when the latter is near the horizon, they will cut off a considerable amount of sky radiation. The hourly totals are thereby reduced by a small but known amount.

The Eppley pyrheliometer was carefully standardized at this office before it was sent to Professor Laurens. The records are reduced by him, using our calibration results.

TABLE 1.—*Solar radiation intensities during March, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance									
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 4	3.00	------	------	0.88	------	------	------	------	------	------	2.62
Mar. 5	2.49	------	0.76	0.89	1.13	------	------	------	------	------	2.49
Mar. 11	8.38	------	0.86	0.92	------	------	------	------	------	------	2.26
Mar. 12	8.58	------	0.83	1.00	1.19	------	------	------	------	------	2.16
Mar. 13	2.49	------	0.92	1.03	1.28	------	------	------	------	------	2.74
Mar. 18	3.45	------	0.84	0.98	1.20	------	------	------	------	------	3.45
Mar. 24	3.00	------	0.74	------	------	------	------	------	------	------	3.45
Mar. 26	5.16	------	0.62	0.81	1.00	------	------	------	------	------	5.16
Means	------	------	**0.80**	**0.93**	**1.16**	------	------	------	------	------	------
Departures	------	------	**+0.00**	**−0.02**	**+0.01**	------	------	------	------	------	------

Madison, Wis.

Mar. 2	2.16	0.97	1.08	1.20	1.36	------	1.35	------	------	------	2.36
Mar. 3	2.62	------	1.04	1.17	------	------	------	------	------	------	2.36
Mar. 4	1.96	1.04	1.03	1.16	------	------	------	------	------	------	1.88
Mar. 9	2.16	------	------	------	------	------	1.30	------	------	------	1.45
Mar. 10	1.96	------	------	1.29	1.43	------	------	------	------	------	1.52
Mar. 11	2.49	------	------	------	------	------	1.33	------	------	------	2.36
Mar. 25	3.99	------	------	------	1.30	------	------	------	------	------	3.81
Mar. 30	2.16	------	1.03	1.16	1.29	1.53	1.31	------	------	------	2.49
Means	------	**(1.00)**	**1.04**	**1.20**	**1.34**	------	**1.32**	------	------	------	------
Departures	------	**+0.02**	**+0.01**	**+0.01**	**+0.03**	------	**+0.03**	------	------	------	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during March, 1931*—Con.

[Gram-calories per minute per square centimeter of normal surface]

Lincoln, Nebr.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 9	1.96				1.40						3.00
Mar. 10	3.15						1.21	0.93	0.78	0.60	3.63
Mar. 13	4.57		0.82	1.01	1.28		1.34		1.03	0.94	5.36
Mar. 14	3.63		0.97	1.08	1.26						3.81
Mar. 15	2.62					1.64	1.43	1.29	1.10	1.00	2.16
Mar. 16	2.36		0.86	1.13	1.32						2.06
Mar. 18	3.99			1.06	1.26		1.29	1.09	0.93	0.78	4.37
Mar. 25	3.15		0.72	1.03							2.49
Means			0.84	1.06	1.30		1.32	1.10	0.96	0.83	
Departures			−0.09	−0.03	+0.03		+0.04	+0.01	+0.01	+0.01	

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
	Average daily totals											
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Feb. 26	314	282	296	184	247	369	185	352	427	339	240	----
Mar. 5	323	331	310	149	198	372	168	472	402	360	259	382
Mar. 12	309	165	423	114	311	321	203	428	448	330	405	348
Mar. 19	286	242	329	276	260	435	180	453	446	356	491	264
Mar. 26	292	287	291	188	204	356	149	508	550	410	430	234
	Departures from weekly normals											
Feb. 26	+26	−5	−49	−5	+17	+75	+14	−40	+57	−7	----	----
Mar. 5	+7	+34	−42	−43	−58	+66	−34	+80	+18	+21	----	----
Mar. 12	−18	−150	+48	−90	+45	−6	−23	+58	+33	−8	----	----
Mar. 19	−69	−79	−69	+55	−6	+85	−47	+56	−26	−14	----	----
Mar. 26	−57	−76	−111	−49	−70	+3	−82	+36	+39	+6	----	----
Accumulated departures on Apr. 1, 1931	−499	−2,898	−1,001	−798	+546	----	−1,179	+1,283	+497	+140	----	----

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1031	*h* *m*	°	°	°			
Mar. 1 (Yerkes Observatory)	12 42	−31.6	265.7	−7.6	24		
		−30.8	266.5	−8.8	18		
		−30.0	267.3	−8.9	17		
		−30.0	267.3	−8.5	35		
		−28.6	268.7	−9.2	34		
		−25.8	271.5	−7.4	17		
		−24.2	273.1	−6.8	17		
		−23.1	274.2	−6.8	08		260
Mar. 2 (Naval Observatory)	11 44	−65.0	219.6	−7.0		62	
		−13.5	271.1	−8.0		216	278
Mar. 3 (Yerkes Observatory)	12 48	−56.2	214.7	−10.3		106	
		−52.8	218.1	−9.2	12		
		−47.2	223.7	−9.5	44		
		−4.3	266.6	−9.2		60	
		−3.9	267.0	−9.6		60	
		+4.4	275.3	−7.6	180		462
Mar. 4 (Naval Observatory)	12 31	−36.0	221.9	−2.5		185	
		+19.0	276.9	−10.0	123		308
Mar. 5 (Naval Observatory)	11 50	−25.0	220.1	−8.0		154	
		+11.0	256.1	−32.0	3		
		+29.0	274.1	−9.0		185	342
Mar. 6 (Naval Observatory)	11 41	−12.0	220.0	−8.5		123	
		+40.0	272.0	−10.0		154	277
Mar. 7 (Naval Observatory)	11 18	+2.0	221.0	−10.0		123	
		+55.0	274.0	−10.5		123	246
Mar. 8 (Mount Wilson)	13 0	−80.0	115.0	+8.0	55		
		+15.0	219.0	−10.0		89	
		+70.0	274.9	−10.0		195	339
Mar. 9 (Naval Observatory)	11 34	−75.0	117.5	+10.0		217	
		+30.0	222.5	−10.5		93	
		+85.0	277.5	−12.0		93	433
Mar. 10 (Naval Observatory)	11 53	−80.0	99.2	+11.5		62	
		−60.0	110.2	+8.0		309	
		+42.0	221.2	−12.0		154	525

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1031	*h* *m*	°	°	°			
Mar. 11 (Naval Observatory)	11 34	−47.0	119.2	+8.0		463	
		+16.0	182.2	−10.0	6		
		+57.0	223.2	−11.0		62	531
Mar. 12 (Naval Observatory)	11 37	−50.0	103.0	+10.5		93	
		+33.0	186.0	+7.5		494	
		+76.0	229.0	−12.0		62	649
Mar. 13 (Naval Observatory)	11 37	−72.0	67.8	+10.5		154	
		−38.0	101.8	+10.0		93	
		−21.0	118.8	+6.5		432	679
Mar. 14 (Naval Observatory)	10 52	−60.0	67.0	+10.0	185		
		−23.0	104.0	+10.0		93	
		−8.0	119.0	+6.0		340	618
Mar. 15 (Mount Wilson)	11 20	−46.0	67.6	+8.0	257		
		−8.0	105.6	+8.0		24	
		+5.0	118.6	+5.0		403	684
Mar. 16 (Mount Wilson)	14 30	−30.0	68.7	+8.0	230		
		+7.0	105.7	+8.0		4	
		+20.0	118.7	+5.0		307	
		+67.0	165.7	−3.0	8		549
Mar. 17 (Naval Observatory)	10 57	−18.0	69.4	+9.0	216		
		+16.0	103.4	+9.0		15	
		+32.0	119.4	+5.0		247	
		+80.0	167.4	+2.0		93	571
Mar. 18 (Naval Observatory)	11 5	−4.0	70.2	+8.0	123		
		+12.0	86.2	+11.0	15		
		+23.0	97.2	+11.5	15		
		+43.0	117.2	+5.0		216	
		+75.0	149.2	−7.0	15		384
Mar. 19 (Yerkes Observatory)	15 41	−22.0	36.5	+7.7	17		
		−19.1	39.4	+7.7	16		
		−2.4	56.1	−19.3		31	
		+0.2	58.7	−20.8	20		
		+10.9	69.4	+6.0		125	
		+57.8	116.3	+4.1		116	
		+57.2	115.7	+6.2		29	
		+65.2	123.7	+1.7	36		
		+62.3	120.8	+7.6	17		
		+60.8	119.3	+10.5	33		440
Mar. 20 (Naval Observatory)	11 51	−8.0	39.4	+9.0		9	
		+10.0	57.4	−20.0		19	
		+23.0	70.4	+7.5	154		
		+80.0	127.4	+1.0		62	244
Mar. 21 (Naval Observatory)	11 1	+8.0	42.7	+9.0	6		
		+25.0	59.7	−21.0	6		
		+37.5	72.2	+7.0	123		135
Mar. 22 (Mount Wilson)	11 30	+23.0	44.2	+7.0	5		
		+39.0	60.2	−22.0	6		
		+50.0	71.2	+6.0	145		156
Mar. 23 (Naval Observatory)	11 48	+65.0	72.8	+5.0	123		123
Mar. 24 (Naval Observatory)	11 38	−75.0	279.8	−5.0	93		
		+80.0	74.8	+6.0	93		186
Mar. 25 (Naval Observatory)	11 29	−62.0	279.7	−6.5	93		93
Mar. 26 (Naval Observatory)	11 40	−48.0	280.4	−6.5	123		
		+75.0	43.4	+18.0	31		154
Mar. 27 (Naval Observatory)	12 18	−32.0	282.8	−7.0	93		93
Mar. 29 (Naval Observatory)	10 46	−9.0	280.3	−8.0	123		123
Mar. 30 (Naval Observatory)	11 37	+8.0	283.6	−8.0	62		62
Mar. 31 (Perkins Observatory)	14 30	−37.0	223.8	+15.0		93	
		+17.0	277.8	+2.0		124	
		+60.0	320.8	−11.0		155	372
Mean daily area for March							344

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR MARCH, 1931 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich Switzerland]

March, 1931	Relative numbers	March, 1931	Relative numbers	March, 1931	Relative numbers
1	Ec 34	11	38	21	26
2	31	12	38	22	25
3	*a* 24	13	*d* 43	23	17
4		14	47	24	*a* 16
5		15	*b* 46	25	8
6		16	41	26	8
7	*a* 28	17	Wc 51	27	8
8		18	*a* 49	28	14
9	*d* 32	19	38	29	16
10	32	20	40	30	9
				31	WEcc 27

Mean: 27 days 29.1.

[1] Dependent alone on observations at Zurich and its station at Arosa.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group through the central meridian.
c = New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. Samuels

Free-air temperatures for March were below normal at all stations with the exception of the 4 and 5 kilometer levels at Ellendale (Table 1). The largest departures occurred at Groesbeck, the southernmost station.

Free-air relative humidities were practically all above normal and the vapor pressures mostly all below normal except at the upper levels at Ellendale, where the latter were above normal. At this station it is noted that the total precipitation for the month was the second largest amount for March since the establishment of the station in 1918.

Resultant winds at the 1,000-meter level were preponderantly northerly over the northern part of the country and westerly over the South Central and Southern States. It is noted that the resultant velocities at that level were appreciably greater over the West Gulf States than over the Northern States.

At 3,000 meters the same general relation occurred except that the velocities were higher.

An ideal condition for the formation of ice on the kites and wire occurred at Due West on the 31st. With a surface temperature of 9° C. the kites entered the cloud base at 1,200 meters, where the temperature was 2° C. Within the clouds the temperature decreased to –2° C. and the kite and wire took on considerable ice, causing four kites to fall to the ground with 4,600 meters of wire.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.8	−3.2	6.6	−4.5	−4.1	−2.1	9.0	−4.3	1.8	−2.5
500	4.9	−3.4	5.3	−4.0	−4.4	−2.2	8.7	−2.9	−0.6	−2.7
1,000	2.9	−3.4	2.8	−3.9	−5.2	−1.7	6.6	−3.5	−3.6	−3.8
1,500	0.9	−3.9	0.2	−4.1	−5.2	−0.6	5.0	−3.8	−5.7	−4.5
2,000	−0.5	−3.5	−1.5	−3.6	−6.7	−0.3	2.8	−4.5	−7.0	−4.1
2,500	−2.9	−3.6	−3.2	−3.1	−9.1	−0.3	0.8	−4.3	−8.9	−3.7
3,000	−5.5	−3.7	−5.7	−3.4	−11.7	−0.1	−1.4	−3.9	−10.9	−3.3
4,000	−12.6	−5.5	−9.1	−1.9	−16.3	+0.7	−9.0	−5.7	−16.2	−3.6
5,000					−22.1	+0.8			−22.2	−3.4

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1931*—Continued

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	65	+1	69	+5	79	+6	75	+4	79	+8
500	65	+3	65	+3	79	+7	64	−3	81	+11
1,000	64	+5	62	+1	74	+10	60	0	81	+17
1,500	61	+9	63	+3	66	+8	50	−1	75	+18
2,000	54	+8	62	+5	63	+7	48	+5	68	+14
2,500	53	+11	59	+6	65	+9	41	+2	63	+11
3,000	54	+14	58	+11	66	+9	35	−2	58	+6
4,000	56	+19	38	−5	71	+18	51	+13	61	+12
5,000					58	+5			63	+9

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. Mean	Departure from normal	Due West, S. C. Mean	Departure from normal	Ellendale, N. Dak. Mean	Departure from normal	Groesbeck, Tex. Mean	Departure from normal	Royal Center, Ind. Mean	Departure from normal
Surface	6.42	−1.80	6.84	−2.22	3.67	−0.27	9.05	−2.52	5.52	−0.82
500	5.66	−1.56	5.94	−1.98	3.61	−0.22	7.46	−2.48	4.71	−0.70
1,000	4.75	−1.18	4.80	−1.78	3.14	+0.12	6.09	−1.93	3.76	−0.59
1,500	3.93	−0.84	3.95	−1.43	2.80	+0.25	4.42	−1.67	2.94	−0.57
2,000	3.03	−0.67	3.38	−0.86	2.33	+0.18	3.60	−0.80	2.35	−0.61
2,500	2.51	−0.43	2.71	−0.52	1.96	+0.18	2.62	−0.78	1.83	−0.63
3,000	2.05	−0.32	2.07	−0.19	1.58	+0.14	1.89	−0.81	1.42	−0.71
4,000	1.41	−0.05	1.54	+0.20	1.11	+0.24	1.91	+0.05	1.09	−0.28
5,000					0.18	−0.38			0.79	−0.27

TABLE 2.—*Free-air data obtained by airplanes at naval air stations during March, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	5.7	10.7	16.9	4.1	60	72	60	64
500	2.7	9.3	15.5	0.7	59	67	61	68
1,000	−0.2	6.6	14.6	−2.0	57	63	46	68
2,000	−4.3	3.3	10.0	−5.6	49	55	32	58
3,000	−8.6	−0.7	4.6	−9.0	42	51	24	48
4,000		−7.2				56		

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during March, 1931*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Brownsville, Texas (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 23 W	1.3	S 25 W	0.5	N 27 E	0.5	N 75 W	5.7	N 81 W	0.6	N 15 W	1.9
500	N 7 W	1.4	S 11 W	4.0	N 22 W	1.8			N 67 W	1.6	N	1.9
1,000	N 85 W	2.7	S 86 W	2.6	N	0.7			N 75 W	3.7	N 14 W	2.2
1,500	N 63 W	6.8	N 78 W	3.4	N 30 W	0.8			N 74 W	5.4	N 44 W	3.2
2,000	N 54 W	8.4	N 82 W	3.9	N	1.6	N 70 W	8.9	N 70 W	8.6	N 39 W	3.6
2,500	N 25 W	12.5	N 65 W	7.4	N 53 W	1.5	N 64 W	13.4	N 74 W	10.7	N 40 W	3.1
3,000			N 62 W	9.9	N 86 W	3.8	N 49 W	11.4	N 63 W	12.0	N 56 W	3.6
4,000			N 64 W	9.8	S 77 W	7.3	N 52 W	12.2	N 60 W	13.6	N 47 W	8.6
5,000									N 69 W	17.7		

Altitude (meters) m. s. l.	Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 33 W	1.1	S 59 W	1.6	N 75 W	1.4	N 27 E	0.9	N 33 E	2.0	N 20 W	0.1
500	N 69 W	2.5			N 60 W	6.0	S 22 E	0.3	N 68 E	1.2	S 74 W	0.4
1,000	N 66 W	5.4	S 78 W	3.6	N 78 W	6.7	S 68 W	3.3	N 3 E	2.4	S 40 W	1.0
1,500	N 49 W	7.0	N 78 W	7.0	N 85 W	7.8	S 70 W	4.8	N 8 W	2.8	S 30 W	2.4
2,000	N 54 W	8.0	N 74 W	7.8	N 82 W	10.7	S 78 W	5.9	N 20 W	3.6	S 51 W	2.5
2,500	N 41 W	11.1	N 71 W	8.5	N 78 W	12.6	S 86 W	7.7	N 25 W	2.8	S 75 W	3.2
3,000	N 40 W	12.7	N 70 W	8.9	N 82 W	15.3	N 88 W	9.3	N 34 W	4.6	N 66 W	3.4
4,000					W	16.7	N 78 W	12.0	N 24 W	6.5	N 46 W	2.7
5,000					N 88 W	18.9						

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during March, 1931*—Continued

Altitude (meters) m. s. l.	Memphis, Tenn. (145 meters) Direction	Velocity	Modena, Utah (1,665 meters) Direction	Velocity	New Orleans, La. (25 meters) Direction	Velocity	Omaha, Nebr. (299 meters) Direction	Velocity	Phoenix, Ariz. (356 meters) Direction	Velocity	Royal Center, Ind. (225 meters) Direction	Velocity
	°		°		°		°		°		°	
Surface	S 69 W	1.0	N 79 W	2.0	N 36 W	1.3	N 21 E	1.7	S 86 E	2.4	N 39 W	1.4
500	N 82 W	1.9	----	----	N 53 W	3.4	N 17 E	2.0	N 82 E	2.3	N 15 W	2.7
1,000	N 69 W	5.5	----	----	N 71 W	4.2	N 2 W	2.5	N 19 E	1.5	N 5 E	3.1
1,500	N 67 W	6.9	----	----	N 77 W	4.7	N 25 W	5.5	N 20 W	1.7	N 1 W	3.7
2,000	N 78 W	7.9	N 13 E	1.3	N 70 W	6.7	N 35 W	7.1	N 46 W	2.5	N 29 W	4.8
2,500	N 71 W	9.0	N 3 W	2.8	N 69 W	9.1	N 33 W	9.0	N 36 W	4.1	N 30 W	5.6
3,000	----	----	N 20 W	4.8	N 80 W	9.9	N 45 W	10.0	N 39 W	5.6	N 44 W	6.0
4,000	----	----	N 45 W	9.1	----	----	N 34 W	12.4	N 49 W	6.2	N 61 W	8.4
5,000	----	----	N 48 W	13.1	----	----	----	----	----	----	----	----

Altitude (meters) m. s. l.	Salt Lake City, Utah (1,294 meters) Direction	Velocity	San Francisco, Calif. (8 meters) Direction	Velocity	Sault Ste. Marie, Mich. (198 meters) Direction	Velocity	Seattle, Wash. (14 meters) Direction	Velocity	Spokane, Wash. (606 meters) Direction	Velocity	Washington, D. C. (10 meters) Direction	Velocity
	°		°		°		°		°		°	
Surface	S 4 E	1.7	S 47 E	0.4	N 45 E	1.4	S 19 E	1.5	S 16 E	1.6	N 28 W	2.0
500	----	----	N 27 W	2.5	N 51 E	4.3	S 19 W	5.9	----	----	N 18 W	5.6
1,000	----	----	N 14 W	4.9	N 54 E	2.7	S 33 W	6.1	S 30 W	4.3	N 38 W	7.0
1,500	S 11 E	2.2	N 25 W	4.2	N 41 E	3.3	S 68 W	3.7	S 62 W	4.6	N 52 W	7.2
2,000	S 65 W	1.4	N 28 W	3.8	N 67 E	3.6	S 71 W	3.2	S 86 W	4.9	N 64 W	7.0
2,500	N 69 W	3.5	N 47 W	6.0	N 4 E	3.0	N 2 W	3.1	N 81 W	6.3	N 59 W	8.0
3,000	N 56 W	5.5	N 56 W	5.9	N 20 W	4.1	N 4 E	5.9	N 89 W	6.2	N 64 W	9.2
4,000	N 52 W	6.0	N 43 W	5.1	N 12 E	5.7	----	----	----	----	N 78 W	13.4
5,000	N 19 W	11.4	----	----	N 28 W	6.4	----	----	----	----	----	----

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during March, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,608	2,517	3,184	2,222	2,864
Maximum altitude (meters), m. s. l., reached	4,498	4,493	4,998	4,264	[1] 9,445
Number of flights made	34	33	33	30	33
Number of days on which flights were made	30	31	28	30	30

In addition to the above, there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

[1] Limited-height sounding balloon observation.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The weather for March, as a whole, was persistently cool throughout the central and southern portions of the country from the Rocky Mountains eastward to the Atlantic, while the northern and western sections were warm for the season; however, during the last week a severe cold wave overspread the northwestern and central-western areas, and in some sections the lowest temperatures of the winter occurred during this period, with heavy snow as far south as northwestern Texas.

For the month as a whole the precipitation continued below normal in most sections east of the Great Plains and in large areas west of the Rocky Mountains. The Pacific Northwest, the Great Plains and the extreme Southeast, and the North Atlantic section had much more than the average, while a few localities received nearly twice the normal. The greatest shortage occurred from the Ohio Valley southward nearly to the Gulf and in the far Southwest, especially the lower Colorado Valley, Nevada, and southern California.

TEMPERATURE

The first decade of March was mainly warmer than normal near the Pacific coast and in the northern portion of the country, but colder than normal in the middle and southern portions from the Sierra crest to the Atlantic coast. The period from the 6th to 9th was especially cold in the middle and southern Plateau, Rocky Mountain, and Plains regions.

The fortnight from the 11th to the 24th was mostly warmer than normal in the western half of the country and from Minnesota to New England, but colder than normal in the middle and southern portions of the eastern half, especially the South Atlantic and East Gulf States.

The final week of March was marked almost everywhere by cold weather, especially from the western Plateau to the Mississippi River. The districts from the Black Hills southward to northwestern Texas and central Oklahoma averaged at least 15° colder than normal. However, most of California and the Northeast continued warmer than normal.

The month averaged warmer than normal in the Pacific States and a large part of the Plateau region, also in the northernmost third of the country. The northern portions of New England and New York and the vicinity of Lake Superior and the Red River of the North averaged mainly 4° to 6° above normal. The most marked excess of the monthly temperature was in southwestern California, where Los Angeles noted a mean of 66°, over 8° above normal, making this not only the warmest March but warmer than any recorded April or May.

From New Mexico and eastern Utah eastward to the Atlantic coast from Delaware Bay to Florida the month averaged colder than normal, and to the southward of the Potomac and Ohio Rivers and the southern parts of Missouri and Kansas the deficiency averaged 4° to 7°. In Florida it was almost the coldest March ever known.

The highest marks were generally not notable for March, but one station each in Arizona and California noted 100°. In many States, even as far south as Missouri and Virginia, no temperature exceeding 70° was recorded. In the western half the highest temperatures usually occurred about the 22d, near the Mississippi River about the 13th, but from Michigan and the middle Ohio Valley eastward between the 23d and the 28th.

The lowest readings were considerably below zero in the northernmost States and as far south as Nebraska; also in

most mountain and plateau States. In the eastern half the coldest weather came usually about the 4th or else early in the second decade. Most of the western half experienced its coldest weather about the 27th. At Havre, Mont., −4°, on March 26, was lower than any reading since November 15, last, save one day in January when the same mark was noted.

PRECIPITATION

The monthly amounts of precipitation are given in Table 1, p. 134.

During the first decade there was precipitation in moderate amounts over much of the eastern half of the country, the amounts being especially heavy in the region of the central valleys, and fairly heavy near Lake Michigan and the east Gulf and New England coasts.

The fortnight from the 10th to the 24th brought light to moderate amounts to numerous areas, especially the Pacific Northwest, the northern Plains and thence eastward as far as the western end of Lake Superior and much of Texas and the South and Middle Atlantic States.

The final week brought more precipitation to a large part of the country than any preceding week of March. Most districts received moderate to considerable amounts, save the Rio Grande Valley and areas westward to the south Pacific coast, a broad belt from Montana to Minnesota, and the upper Ohio Valley and the Carolinas.

As a whole, March brought considerably more moisture than any of the months just preceding, and the distribution was comparatively favorable. No State received twice the normal March quantity, on the average, and only in Arizona and California was less than half the normal received.

There usually was more than normal in Washington, Oregon, and Idaho, especially in the western part of the last named and near the lower Columbia River. Much of New Mexico and Texas, nearly all of the Plains, several parts of the Lake region, and most of the upper Mississippi Valley had somewhat more precipitation than normal. Southern Florida received much more rain than normal, and the rest of the east Gulf coast region a trifle more, while from Chesapeake Bay to Maine there was a moderate excess of precipitation.

There was a considerable deficiency from the central portions of Georgia, Alabama, and Mississippi northward to northern Ohio and Indiana; likewise in most of the middle and northern Rocky Mountain regions. The chief area of marked shortage embraced the middle and southern Plateau and Pacific regions, the scarcity of rain being notable in southwestern Arizona and far southern California.

A few stations in Oregon and Washington measured about 30 inches during March, but east of the Pacific States the greatest amount reported was 9.25 inches at a station in Florida. In Maryland, where the monthly precipitation averaged above normal for the first time since November, 1929, every station measured more than 3 inches, while in Kentucky and the Virginias, where once more the average was less than normal, the distribution was yet so favorable that the least amount reported was 1.54 inches.

SNOWFALL

The month's snowfall (see Table 1 and Chart VII) was more than normal over most central and north-central portions, and was usually greater than for any preceding month of the winter. From Kansas to the middle Ohio Valley the quantities were generally more than twice the normal, and in the Lake region, New England, and the western half of the Middle Atlantic States somewhat greater than normal.

The eastern half of the Middle Atlantic States had less than normal and the same was true of Tennessee. Minnesota likewise received somewhat less than normal.

In the far West there was comparatively little snowfall, and the elevated portions of central and southern California received particularly little. Parts of Idaho, however, and much of the Rocky Mountain region received moderately heavy falls, with somewhat improved outlook resulting as to the water supply of the coming season.

The most important falls of snow occurred from eastern Kansas to western New York about the 5th to the 11th, and over most of the Rocky Mountain and Plains regions and part of the Great Basin during the final week. This latter storm gave notable large amounts in the western portion of the central and southern Plains, where the snowfall was accompanied by intense winds and very low temperatures.

SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed from the eastern Great Plains eastward, except in the South. It was unusually cloudy in the upper Ohio Valley, the lower Lake and central Appalachian regions. Parkersburg, W. Va., reports the cloudiest month of record. In the Gulf States 50 per cent or more sunshine prevailed, while in the far Southwest from 70 to 80 per cent or more was received. In the central and northern Great Plains, and eastward to the Atlantic the relative humidity was generally above normal, except in Iowa and portions of adjacent States; while elsewhere it was generally below the average. The departures as a rule were not large, except in a few localities in the far West.

SEVERE LOCAL STORMS, MARCH, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annua Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Ventnor and Atlantic City, N. J.	4					Gale and high tide.	Part of pier swept away; boardwalk damaged.	Washington Post (D. C.).
Long Island, N. Y.	4					do	Seaside cottages damaged; greatest havoc at East Hampton.	Washington News (D. C.).
New England coast	4				$2,000,000	Wind and storm tides.	Several towns partly inundated; cottages wrecked; merchandise soaked; roads washed out; traffic stalled. Severest damage between Boston and Salem, Mass.	Evening Star (Washington, D. C.).
North-central States (parts of).	5–9					Snow, wind, glaze.	Wires, poles, and trees damaged; highways obstructed; trains off schedule.	Official, U. S. Weather Bureau
Bossier City, La.	6	8 p. m.	66–440		5,000	Tornado	5 buildings practically demolished; telephone poles blown down; path 3 miles long.	Do.
Memphis, Tenn.	7					High wind	Steamer George Woods sunk	Do.
Ashury Park to Sandy Hook, N. J.	8				75,000	Wind and high tides.	Chief damage by water, character not reported.	Do.

Severe local storms, March, 1931—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Knoxville, Tenn. (near)	8					Snow	Minor property damage	Official, U. S. Weather Bureau.
Memphis, Tenn	8					High winds	Two boats blown from dock and sunk	Do.
Maryland (central part)	8					do	Some buildings damaged, especially in Washington County.	Do.
Northport section of Long Island, N. Y.	8				50,000	do	Summer homes and bathhouses damaged	Do.
Westchester County, N. Y.	8					do	Thousands of dollars damage to houses, trees, signs, windows, and telephone and power lines.	Do.
Massachusetts, New Hampshire and Vermont.	8–9					Snow and wind	Transportation crippled over large area	Do.
Eastern Shore, Virginia and Maryland.	16–17				$1,000,000	Heavy snow and high winds.	Damage chiefly to overhead wires	Do.
Desdemona, Tex	19	7.45 p. m.	1,760			Wind and hail	Damage chiefly to oil derricks; gardens injured.	Do.
Clinton, Okla	19	p. m.		2	60,000	Tornado	Store and school annex demolished; 12 homes unroofed; a score of persons injured; path 3 blocks wide.	Washington News (D. C.).
Pensacola, Fla	21	a. m.				High wind	2 boats beached; sign boards blown down: windows broken.	Official, U. S. Weather Bureau
Colorado, Iowa, Kansas, Missouri, Nebraska, Oklahoma, Wisconsin, and Wyoming, parts of.	25–28			25		Blizzard	Highways and country roads impassable; thousands of cattle killed; great loss of sheep and hogs; trains delayed; 5 children died in school bus stalled near Towner, Colo., on the 27th; scattered deaths elsewhere.	Do.
Kerr, Kendall, and Blanco Counties, Tex.	27	12.15 a. m.–1 a. m.	[1] 15 mi.		10,000	Hail	Considerable damage to crops, gardens, and buildings; some loss of livestock.	Do.
Jacksonville, Fla	28					Wind squall	Considerable damage to trees and hanging signs; small pleasure yacht damaged dock and boat slips.	Do.
Macedonia, Fla. (near)	28	4–5 p. m.				Wind	Small buildings unroofed; trees uprooted	Do.
Mulberry to Winter Haven, Fla.	31	9.30 a. m.–10.30 a. m.	100		50,000	Tornado	A number of residences damaged, 1 completely demolished; considerable injury to groves; several persons injured; path 20 miles long.	Do.
Indian River City, Fla	31	11.30 p. m.			2,000	Wind	1 residence, several garages, and a water tank damaged.	Do.
Talbot, Meriwether, and Upson Counties, Ga.	31				30,000	Series of severe hailstorms.	Damage almost entirely to peach trees; 4 persons injured.	Do.
Alabama (central and southern counties).	31			1		Hailstorms and 2 tornadoes.	Considerable damage to farm buildings and other property in Coffee and Elmore Counties by tornadoes; damage by hail in Clinton County.	Do.

[1] Mi. signifies miles instead of yards.

RIVERS AND FLOODS

By MONTROSE W. HAYES

Floods in March were of minor consequence. The few rivers that overflowed were out of banks for a very short time and no high stages were reached.

During the week beginning March 22 the temperatures were in the fifties and snow melted rapidly over the upper part of the Susquehanna Basin, in New York. Rain late in the week further augmented the melting and the Chenango and Tioughnioga Rivers and smaller streams ran bankful. Some highways along the Tioughnioga were flooded, and a man was drowned, due to the overturning of a canoe by the swift current, at Blodgetts Mills, near Cortland, N. Y. There was no other flooding in the Atlantic Seaboard drainage.

The St. Francis River, in southeast Missouri and northeast Arkansas, and the Black River, in northeast Arkansas, were out of their banks in the second week of the month, but the overflow was slight and the damage was almost negligible.

The Sulphur River, a tributary of the Red, was in very moderate flood twice. The rises were rapid and there was a total loss of about $12,000 in livestock, and about an equal saving made possible by the flood warnings.

In the Trinity River, in Texas, there were slight overflows during the first half of the month. The damage was confined to levees under construction.

Some of the rivers of Washington and Oregon were in flood on March 31. These floods will be considered in the April, 1931, MONTHLY WEATHER REVIEW.

The following reports from officials in charge of Weather Bureau offices are considered of interest:

Cairo, Ill.—Ohio River dams in this district were lowered on February 14, except No. 52, which remained up till February 17. The dams had been up since the last week in May, 1930. They were originally intended as an aid to navigation in the summer and autumn low-water periods, but the prolonged drought made necessary their operation through the winter.

New Orleans, La.—The Mississippi and Atchafalaya Rivers were unusually low for the season. Lower stages have been recorded, notably in the first half of March, 1895, but the absence of any material rise in March, 1931, gave an average stage of 3.1 feet on the Carrollton (New Orleans) gage, which is lower than any previous average stage for the month.

Table of flood stages in March, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Chenango: Sherburne, N. Y	8	29	29	8.1	29
MISSISSIPPI DRAINAGE					
St. Francis:					
Chaonia, Mo	22	8	9	23.8	9
Fisk, Mo	20	9	12	23.2	10
St. Francis, Ark	18	13	17	19.4	15
Black: Black Rock, Ark	14	8	12	17.5	9
Sulphur: Ringo Crossing, Tex	20	3	5	24.0	3
		28	28	22.0	28
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex	28	1	5	31.8	3
		8	9	28.7	8
Trinidad, Tex	28	6	10	29.5	8–9
PACIFIC DRAINAGE					
North Santiam: Mehama, Oreg	15	31	(1)	15.5	
Santiam: Jefferson, Oreg	10	31	(1)	15.5	
Willamette: Harrisburg, Oreg	10	31	(1)	10.6	

[1] Flood continued into April.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather conditions over the North Atlantic during March were abnormal in some respects. Table 1 shows the exceptionally large negative departure at Horta, which indicates that an area of low pressure displaced the usual North Atlantic HIGH during the greater part of the month. While no reliable normal is available for Julianehaab, Greenland, an examination of the barometric readings at that station for a number of years shows that the positive departure for the current month was probably not far from 0.50 inch. Table 1 also gives an unusually large positive departure at Lerwick, Shetland Islands, which according to the Pilot Chart, is situated not far from the southern limit of the Icelandic LOW. It is not strange, therefore, that due to the reversal of the normal pressure distribution, the usual "westerlies" were replaced at times by winds of gale to hurricane force from all points of the compass, over a large section of the steamer lanes.

Judging from reports received, the number of days with gales was considerably above normal over the region between the Azores and the American coast, where they were reported on from 5 to 6 days in different 5° squares, while they were less prevalent than usual north of the forty-fifth parallel, occurring on from 4 to 5 days in any one square.

The number of days on which fog was reported in different localities is as follows: Over the Grand Banks, from 3 to 6 days; along the American coast, between the thirty-fifth and forty-fifth parallels, from 2 to 7 days; over the steamer lanes, between the tenth and forty-fifth meridians, from 2 to 4 days; along the European coast, from 3 to 9 days; in the vicinity of the Madeiras, 2 days; in the Gulf of Mexico, 1 day.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, March, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.97	(1)	30.42	11th	29.20	6th.
Belle Isle, Newfoundland	30.02	[2]+0.22	30.54	28th	29.00	1st.
Halifax, Nova Scotia	29.85	[3]−0.11	30.48	28th	28.86	5th.
Nantucket	29.84	[3]−0.18	30.32	28th	29.16	4th.
Hatteras	29.90	[3]−0.20	30.28	27th	29.22	3d.
Key West	30.00	[3]−0.08	30.24	13th	29.76	31st.
New Orleans	30.03	[3]−0.06	30.28	9th	29.64	31st.
Cape Gracias, Nicaragua	29.93	[2]−0.05	29.98	10th [4]	29.90	2d.[4]
Turks Island	30.04	[2]+0.02	30.18	13th	29.86	3d.
Bermuda	29.88	[3]−0.26	30.16	7th	29.52	4th.
Horta, Azores	29.63	[2]−0.49	30.06	22d	29.16	16th.
Lerwick, Shetland Islands	30.04	[2]+0.34	30.55	24th	29.53	13th.
Valencia, Ireland	29.79	[2]−0.11	30.36	24th	29.35	19th.
London	29.95	[2]−0.01	30.48	25th	29.62	1st.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other dates.

56409—31——3

Charts VIII to XIII cover the period from the 1st to 6th. Charts VIII and IX give the position of the LOW that appears on Charts X and XI for February 27 and 28, respectively, while Charts X to XIII show the conditions from the 3d to 6th, when exceptionally severe weather prevailed over different sections of the ocean. From the 3d to 5th the American coast was swept by the most severe storm of the month, reaching its greatest intensity and extent on the 4th, while on the same day westerly gales also occurred in the vicinity of the Azores.

From the 7th to 10th heavy weather still prevailed between the Azores and fiftieth meridian, while on the 7th Pensacola was near the center of a LOW, and on that date as well as on the 8th moderate gales were reported in the Gulf of Mexico. The barometric reading at Pensacola rose from 29.60 inches on the 7th to 30.16 inches on the 9th, and on the latter date a "norther" was over the western section of the Gulf, where vessels reported northerly winds, force 7 and 8, with barometric readings of from 30.22 to 30.38 inches. The LOW reported near Pensacola on the 7th moved northeastward and was central near Washington on the 8th; thence it continued in its northeasterly movement, accompanied by moderate to strong gales.

On the 11th and 12th gales of force 8 and 9 occurred over the middle section of the steamer lanes, and on the 12th to 14th westerly and northwesterly gales were also reported in the vicinity of the Bermudas.

On the 14th a depression was central about 300 miles northwest of the Azores that drifted slowly eastward and developed into a severe disturbance; during the period from the 15th to 17th westerly to northwesterly winds of from force 8 to 11 pervailed between the twenty-fifth and forty-fifth meridians.

On the 17th there was also a LOW off the Virginia Capes that moved northeastward, and moderate to whole gales were encountered over a limited area, between the thirty-fifth and forty-fifth parallels, during the period from the 17th to 19th.

From the 18th to 21st heavy weather was reported by a number of vessels in the steamer lanes, although on the 20th and 21st moderate weather prevailed over the greater part of the ocean.

On the 22d westerly winds of moderate gale force occurred off the west coast of Florida, and on the 23d the center of the LOW was about 200 miles east of Hatteras, while the disturbance had increased in both intensity and extent. On the 22d there was also a LOW central near 40° N., 50° W., that moved steadily eastward, the storm area covering a considerable portion of the steamer lanes from the 23d to 25th.

From the 26th to 31st moderate weather was the rule over the greater part of the ocean, although gale reports were received from vessels in widely separated localities. On the 31st a well-developed depression was over the eastern section of the Gulf of Mexico, and on the same day the land station at Tampico, Mexico, reported a northerly wind, force 9, barometer 30.04 inches.

OCEAN GALES AND STORMS, MARCH 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Elkhorn, Am. S. S.	Houston	Bremen	40 00 N	50 00 W	Mar. 1	2 a, 1	Mar. 2	29.07	WNW	NNW, 8	W	W, 11	WSW-WNW.
Gatun, Hond. S. S.	New Orleans	New York	29 30 N	79 40 W	Mar. 3	2 a, 3	Mar. 4	29.31	N	NW, 10	N	N, 12	N-NW.
Standard Arrow, Am. S. S.	Beaumont	do	31 18 N	76 01 W	do	6 a, 3	Mar. 3	28.99	W	W, 12	W	—, 12	W-WNW.
Zacapa, Am. S. S.	Santa Marta	do	34 10 N	74 33 W	do	10 a, 3	Mar. 4	28.96	E	NE, 10	NW	NE, 12	NE-N-NW.
San Tirso, Br. S. S.	Minatitlan	United Kingdom.	31 45 N	63 30 W	do	6 p, 3	Mar. 8	29.38	S	SSW, 9	NW	SSW, 10	S-SW-W.
Nosa Prince, Am. S. S.	Canal Zone	Tampico	11 45 N	80 12 W	do	Mdt, 3	Mar. 5	29.81	N	N, 8	NE	—, 9	N-NE.
Knoxville City, Am. S. S.	New York	Port Said	39 54 N	45 48 W	Feb. 27	2 a, 3	Mar. 4	29.18	WNW	NW, 6	W	NW, 10	NW-W.
Quaker City, Am. S. S.	Hull	Philadelphia	41 15 N	66 40 W	Mar. 3	2 p, 4	Mar. 5	28.82	NNW	NNW, —	NW	NE, 12	
San Macedonio, Br. S. S.	Puerto Mexico.	United Kingdom.	40 45 N	57 27 W	do	7 a, 4	do	28.90	E	ESE, 3	SW	E, 11	E-S-SW.
Gonzenheim, Ger. S. S.	Hamburg	Charleston	31 56 N	73 35 W	Mar. 4	Noon, 4	do	29.36	S	W, 8	NW	—, 10	S-W.
Samland, Belg. S. S.	Halifax	London	43 00 N	60 56 W	do	2 a, 5	do	28.80	E	SSW, 9	SW	ENE, 12	ENE-S-SSW.
Persephone, Danzig M. S.	Bremerhaven	Las Piedras	44 40 N	19 30 W	Mar. 5	8 p, 5	Mar. 6	28.94	S	SW, 8	NW	—, 10	SSW-SW.
River Hudson, Br. S. S.	Oran	Boston	35 46 N	57 07 W	Mar. 6	3 a, 6	do	29.52	WSW	WSW, 8	WNW	WNW, 11	Steady.
Nosa Prince, Am. S. S.	Canal Zone	Tampico	22 21 N	89 05 W	Mar. 7	1 p, 7	Mar. 9	29.91	NNW	NNW, 7	NNW	—, 9	N-NE-NNW.
Boston City, Br. S. S.	Fowey	Boston	46 52 N	37 48 W	Mar. 6	4 a, 7	do	28.92	ESE	N, 10	N	N, 10	SW-W-N.
Marie Leonhardt, Ger. S. S.	Charleston	Bremen	48 40 N	15 25 W	Mar. 7	2 p, 7	do	29.28	E	E, 8	E	E, 10	Steady.
Momus, Am. S. S.	New York	New Orleans	35 50 N	75 10 W	Mar. 8	1 p, 8	Mar. 10	29.34	WSW		W	W, 10	WSW-W.
Berlin, Ger. S. S.	do	English Channel.	41 40 N	58 22 W	Mar. 9	2 p, 9	Mar. 9	29.49	SE	SE, 10	SSE	—, 10	ESE-SSE.
Extavia, Am. S. S.	Gibraltar	Boston	37 00 N	17 50 W	Mar. 10	2 a, 10	Mar. 10	29.38	S	S, 7		—, 10	S-WSW.
Ala, Am. S. S.	New York	Antwerp	45 10 N	44 04 W	do	Noon, 11	Mar. 11	29.28	SE	SSE, 10	WSW	—, 10	SE-S-SSW.
Duquesne, Am. S. S.	Manchester	New Orleans	38 39 N	40 53 W	Mar. 14	9 a, 15	Mar. 17	29.25	W	W, —	NW	NW, 10	W-NW.
Guadeloupe, Fr. S. S.	St. Nazaire	Canal Zone	40 25 N	19 17 W	do	8 a, 15	Mar. 18	29.10	ESE	SW, 6	NW	SW, 11	
Standard, Am. S. S.	Baton Rouge	New York	38 25 N	74 30 W	Mar. 16	Mdt, 16	Mar. 17	29.70	NW	NNW, 8	NW	—, 10	Steady.
Emanuel Nobel, Belg. S. S.	Rotterdam	do	40 38 N	68 11 W	do	Mdt, 16	Mar. 16	29.54	E	NE, —	NNE	NE, 10	E-N-NNW.
Mercier, Belg. S. S.	Antwerp	Canal Zone–	36 00 N	35 20 W	do	1 a, 16	Mar. 17	29.49	W	NW, 10	NW	NW, 10	Steady.
Tulsa, Am. S. S.	Manchester	Charleston	46 00 N	24 26 W	Mar. 17	6 p, 17	Mar. 18	28.99	N	N, —	N	N, 10	Do.
Steel Age, Am. S. S.	Port Said	Mobile	30 40 N	56 53 W	do	11 p, 17	Mar. 17	29.76	S	S, 12	W	S, 12	S-W.
Extavia, Am. S. S.	Gibraltar	Boston	37 10 N	51 50 W	Mar. 19	1 a, 19	Mar. 20	29.66	WSW	WSW, 9		—, 10	WSW-W.
West Maximus, Am. S. S.	Antwerp	Mobile	25 40 N	83 30 W	Mar. 21	—, 22	Mar. 22	29.97	W	W, —	NE	W, 8	W-WNW.
Karlsruhe, Ger. S. S.	Bremerhaven	New York	43 42 N	51 25 W	Mar. 18	2 a, 22	do	29.22	N	N, 9	NW	—, 9	
West Cawthon, Am. S. S.	Trinidad	Boston	37 20 N	68 25 W	Mar. 22	2 p, 22	Mar. 23	29.25	E	E, 10	E	E, 10	E-S.
Tampa, Am. M. S.	Port Said	do	43 05 N	38 53 W	do	4 a, 23	Mar. 25	29.10	S	SSE, 5	N	WNW, 10	S-SSE-W.
Viborg, Dan. S. S.	Norfolk	London	47 50 N	30 10 W	Mar. 23	4 p, 25	do	29.67	S	SE, 10	SSE	SE, 10	SE-SSE-SE.
Persephone, Danzig M. S.	Las Piedras	Southampton	34 00 N	47 20 W	Mar. 28	4 a, 29	Mar. 30	29.45	SE	N, 10	NNE	N, 10	NE-N-NNE.
Nosa King, Am. S. S.	W. coast South America.	New Orleans	25 00 N	86 50 W	Mar. 30	—, 31	Apr. 1	29.73	E	SW, 7	NW	WNW, 10	SW-WNW.
NORTH PACIFIC OCEAN													
Emp. of Asia, Can. S. S.	Yokohama	Vancouver	45 58 N	166 22 E	Feb. 28	10 p, 1	Mar. 4	28.49	ENE	NW, 7	SW	W, 9	ENE-NW-N.
San Luis Maru, Jap. M. S.	Kudamatsu	San Pedro	40 53 N	172 20 W	Mar. 1	6 p, 2	Mar. 3	29.24	SE	SW, 7	WNW	S, 9	SSW-SW-W.
Bellingham, Am. S. S.	Tacoma	Yokohama	49 46 N	174 12 E	do	10 p, 2	do	28.42	SE	SSE, 9	SW	SW, 10	SE-S.
Pres. Pierce, Am. S. S.	Victoria	do	48 15 N	168 00 E	do	4 a, 2	Mar. 5	28.60	SE	NW, 12	NW	NW, 12	SSE-NW-W.
Pres. Jefferson, Am. S. S.	Yokohama	Victoria	49 47 N	176 20 W	Mar. 2	8 p, 2	Mar. 2	29.23	SE	SSE, 9	S	SSE, 9	SE-SSE.
Golden Sun, Am. S. S.	Otaru	San Francisco	47 03 N	155 10 W	do	10 a, 3	Mar. 4	29.77	S	S, 11	WSW	S, 11	Steady.
Pres. Grant, Am. S. S.	Yokohama	Honolulu	36 06 N	152 48 E	Mar. 4	10 a, 5	Mar. 5	29.57	WSW	SSW, 9	NNW	SSW, 9	SW-WNW.
Manoa, Am. S. S.	San Francisco	do	37 34 N	123 21 W	do	6 p, 4	do	29.86	W	W, 9	W	W, 9	Steady.
Steel Worker, Am. S. S.	Kahului	Yokohama	33 15 N	142 55 E	do	12 p, 4	do	29.58	S	SSW, —	NW	SSW, 9	SSW-WSW.
Oregon, Am. S. S.	Chefoo	Portland	46 40 N	179 30 E	do	7 p, 4	do	29.13	WSW	WSW, 10	W	WSW, 12	WSW-W.
Kiyo Maru, Jap. S. S.	Tokuyama	San Pedro	40 50 N	153 00 E	Mar. 5	8 a, 5	Mar. 6	28.98	NNE	N, 8	W	WNW, 9	4 pts.
Soyo Maru, Jap. M. S.	Portland	Yokohama	49 20 N	165 00 E	do	2 a, 5	do	28.15	SE	ESE, 6	NW	WNW, 12	ESE-WNW.
Bellingham, Am. S. S.	Tacoma	do	46 52 N	163 45 E	do	Mdt, 5	Mar. 7	28.18	E	S, 6	WNW	NW, 10	SE-S-W.
Atago Maru, Jap. M. S.	Yokohama	San Francisco	41 00 N	164 00 E	do	8 p, 5	do	29.05	SW	SW, 8	W	W, 10	SW-W.
Somedono Maru, Jap. S. S.	Muroran	Columbia River.	48 17 N	173 51 E	do	8 p, 6	do	28.22	SE	SSW, 11	WSW	SW, 11	SSW-SW.
Akagisan Maru, Jap. M. S.	Yokohama	San Francisco	42 00 N	176 02 W	Mar. 6	6 a, 6	Mar. 6	29.43	S	SW, 9	SW	SW, 9	S-SW.
Courageous, Am. M. S.	Shanghai	San Pedro	36 40 N	147 30 E	Mar. 7	3 p, 8	Mar. 8	29.23	SSE	SW, 8	NW	SW, 10	SSE-SW-S.
San Pedro Maru, Jap. M. S.	Moji	San Francisco	36 59 N	150 41 E	do	—, 7	do	29.24	S	SW, 8	NW	SSW, 9	S-SW-W.
Kiyo Maru, Jap. S. S.	Tokuyama	San Pedro	44 29 N	169 18 E	Mar. 8	4 p, 8	Mar. 9	28.52	SE	SW, 8	WSW	WSW, 9	4 pts.
Bellingham, Am. S. S.	Tacoma	Yokohama	44 32 N	158 30 E	do	8 a, 8	do	28.44	SSE	N, 10	WNW	N, 10	SSE-N.
Elmworth, Br. M. S.	Shanghai	Victoria	44 02 N	161 00 E	do	8 a, 8	do	28.47	WNW	SW, 6	W	NW, 10	SW-WNW.
Dakotan, Am. S. S.	Los Angeles	New York	13 53 N	96 26 W	do	2 p, 8	do	29.93	NE	NE, 10	N	NE, 10	NE-NNE-N.
Heian Maru, Jap. M. S.	Yokohama	Seattle	42 51 N	156 05 E	Mar. 7	4 a, 8	Mar. 10	28.74	SSW	W, 5	SSW	—, 10	WSW-W.
Chief Capilano, Br. S. S.	Karatsu	Vancouver	46 37 N	165 47 E	Mar. 10	11 a, 10	do	29.01	E	NE, 3	SW	S, 10	S-SSW-S.
Bellingham, Am. S. S.	Tacoma	Yokahoma	40 01 N	147 37 E	Mar. 11	8 a, 12	Mar. 14	29.08	SE	NW, 7	N	NW, 11	SE-S-WNW
San Diego Maru, Jap. M. S.	Elwood	do	34 04 N	154 40 E	do	10 a, 12	Mar. 15	29.35	E	W, 6	N	WNW, 10	SE-W.
Emilie L. D., Fr. S. S.	Portland	do	34 52 N	166 53 E	Mar. 12	7 p, 12	Mar. 12		SE	SE, 10	W	SE, 10	SE-WSW.
Do	do	do	34 33 N	162 04 E	Mar. 14	7 p, 14	Mar. 19	29.08	W	WNW, 9	N	WNW, 10	W-WNW.
Melville Dollar, Am. S. S.	Legaspi	Los Angeles	39 11 N	175 43 E	Mar. 12	Noon, 13	Mar. 13	29.36	SE	SE, 9	W	SE, 9	SE-S-W.
Eldena, Am. S. S.	San Pedro	Yokohama	31 23 N	162 05 E	Mar. 14	—, 14	Mar. 15	29.56	WSW	WSW, —	WNW	W, 9	SW-W.
Agura Maru, Jap. M. S.	Yokohama	Los Angeles	37 06 N	148 14 E	Mar. 17	8 p, 18	Mar. 17	29.60	SE	SSE, 9	NW	SSE, 9	SSE-W.
Pres. Taft, Am. S. S.	Victoria	Yokohama	39 48 N	146 45 E	Mar. 18	4 p, 18	Mar. 18	29.72	S	SE, 4		NNW, 11	
Grays Harbor, Am. S. S.	Tacoma	do	52 13 N	157 09 W	Mar. 21	3 a, 22	Mar. 22	28.52	ESE	W, 9	WSW	SW, 9	SSW-W.
Admiral Farragut, Am. S. S.	Seattle	Kodiak	59 54 N	145 20 W	Mar. 23	1 a, 23	Mar. 23	29.73	E	E, 10	E	E, 10	E-SW.
Everett, Am. S. S.	Hong Kong	San Francisco	34 10 N	148 25 E	do	6 p, 23	Mar. 26	28.42	SSE	S, 7	NW	SE, 9	
Emma Alexander, Am. S. S.	San Diego	Seattle	37 51 N	122 42 W	Mar. 24	6 p, 24	Mar. 25	29.93	WNW	NW, 5	NNW	NW, 9	Steady.
Grays Harbor, Am. S. S.	Tacoma	Yokohama	49 36 N	167 35 E	Mar. 29	2 a, 30	Mar. 31	29.54	S	SSE, 8	WSW	WSW, 9	WSW-SSE.

[1] Approximate.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—During March, 1931, atmospheric pressure rose generally over that of February throughout the Aleutian region, the Gulf of Alaska, and along the greater part of the American coast and adjacent waters. The Aleutian cyclone remained central on the average, as in the preceding month, over and near the Peninsula of Alaska, with average pressure of 29.65 inches at Kodiak, where a rise of 0.42 inch occurred over the February mean.

The North Pacific anticyclone was in general less well developed than in February, owing to the more frequent intrusion upon its central area by cyclones from higher latitudes. In the main, however, it remained stable over a considerable region off the coast of the United States and in lower middle latitudes, and thence westward into east longitudes.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, at indicated hours, North Pacific Ocean and adjacent waters, March, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	30.50	+0.35	30.90	12th [2]	30.10	24th.
Dutch Harbor [1]	29.76	+0.06	30.32	10th	28.94	3d.
St. Paul [1] [3]	29.81	+0.08	30.40	11th	29.22	4th.
Kodiak [1]	29.65	−0.04	30.30	9th	28.90	21st.
Midway Island [1]	30.00	−0.07	30.34	21st	29.62	27th.
Honolulu [4]	30.06	+0.02	30.15	3d	29.94	29th.
Juneau [4]	29.96	+0.02	30.51	6th	29.17	20th.
Tatoosh Island [4] [5]	30.06	+0.08	30.53	22d	29.47	11th.
San Francisco [4] [5]	30.13	+0.08	30.37	2d	29.79	4th.
San Diego [4] [5]	30.02	0.00	30.26	1st	29.74	25th.

[1] P. m. observations only in averages; a. m. and p. m. in extremes.
[2] And on the 13th.
[3] For 30 days.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—Cyclonic activity was less intense and gales as a consequence were less frequent over that half of the ocean east of 180° longitude than in February. In this region few winds were reported of higher force than 9. Of the exceptions, one was a south gale of force 11 experienced by the S. S. *Golden Sun* southwest of the Gulf of Alaska on the 3d, while the vessel was on the eastern edge of an Aleutian disturbance then centered about 5° south of Dutch Harbor. Another was an east gale of force 10 experienced by the S. S. *Admiral Farragut* in the upper waters of the Gulf of Alaska on the 23d, in connection with a cyclone then central over the eastern part of the Bering Sea.

Going westward from middle longitudes, however, seamen entered a zone of greatly increased storminess and, along the upper routes, of lessened visibility, especially during the early half of the month. From the central Aleutians southward to about 25° or 30° north latitude, and thence westward to the Kuril Islands and Japan, an area is inclosed over which more and severer gales occurred during the first 18 days of March than were experienced during the entire preceding month. After the 18th, storminess was scattered and relatively infrequent.

Along the western extent of the northern steamship routes storm to hurricane velocities were reported on the 2d, 4th, 5th, and 6th between 45° and 50° N., and 165° E. and 180°, in connection with the severest storm field of the month. The disturbance in this region, during the period of greatest intensification, was augmented by two LOWS, one from Siberia, the other from China. The latter left the continent on the 2d and after skirting the east coast of Japan lay east of the Kurils on the 5th. After the 6th the major storm seems to have abated in energy, since from the 7th to the 10th of March no winds exceeding force 10 were reported from its general field. The American S. S. *Bellingham*, westbound between Tacoma and Yokohama, passed through this storm, encountering heavy gales with snow from the 3d, when near 50° N., 165° E., until the 9th, when near 44° N., 156° E. On the 6th the ship was reported as "one mass of ice" from snow and sleet, and on the 7th as hove to on account of gales and thickness of the weather. An offshoot from this storm seems early to have gone eastward and southeastward as a moderate cyclone until the 9th, on which date it was central near 39° N., 142° W. Later it moved northeastward and entered the coast of British Columbia on the 12th.

On the 9th a LOW developed east of Taiwan and proceeded northeastward. By the afternoon of the 12th it had acquired sufficient energy east of northern Japan so that the S. S. *Bellingham*, closely following its recent experience with blinding snow squalls, underwent further stiff weather which culminated in a northwesterly gale of force 11 southeast of Yezo. During the 12th to 14th, connected with the storm development, as it covered a widening field, gales of force 8 to 10 occurred over a considerable expanse of water between latitudes 25° and 40° N. and extending as far east as the one hundred and seventy-fifth meridian of east longitude.

On the 18th, in 39° N., 146° E., the S. S. *President Taft* encountered gales which reached a maximum force of 11 from westnorthwest. The heaviest forces occurred during a rapid rise in pressure following the passage of a moderate disturbance.

Off the central California coast local gales, rising at times to force 9, were reported on the 4th, 5th, and 24th. These were produced by the strong gradients existing between neighboring inland depressions and the eastern ridges of the North Pacific HIGH abutting on the coast.

In the Gulf of Tehuantepec strong northers, maximum force 10, were encountered on the 8th to 10th, during the prevalence of an anticyclone over the southern part of the United States and the Gulf of Mexico.

Winds at Honolulu.—At Honolulu the prevailing wind this March was from the east, but kona winds occurred during 25 per cent of the hours, being unusually frequent for the month. The maximum velocity was 26 miles an hour from the northeast on the 31st. The average hourly velocity was 6.7 miles, which, according to the Honolulu record, is the lowest for the month since the opening of the station in 1904.

Fog and smoke.—There was very little change in the low frequency and scattered formation of fog over most of the ocean over that of the preceding February, the percentage of days with the phenomenon, as reported, not exceeding 10 for the most frequented areas to the westward of the one hundred and thirtieth meridian of west longitude. Along the California coast, however,

fog showed a decided increase in frequency, with a maximum occurrence on about 40 per cent of the days over the region within approximately 100 miles of San Francisco.

On several days of the month, particularly on the 8th and 9th and the 18th to 24th, vessels reported smoke from burning brush which somewhat impeded navigation close on the coasts of Guatemala and Salvador. This most generally prevailed in the early morning, being carried inland by the sea breeze about 8:30 a. m.

THE FIJI ISLANDS STORM OF FEBRUARY 17–MARCH 2, 1931

By WILLIS E. HURD

In an official report dated March 10, 1931, to the Secretary of State, the American consul at Suva, Fiji, Quincy F. Roberts, begins thus:

> The Fiji Islands, during the period February 17 to March 2, 1931, experienced a hurricane and floods said to be the worst in the history of the colony.

Unfortunately there are not yet exact data at hand from which to determine whether one or two cyclones hovered about the islands during this period, although it was not until the 3d of March that westerly winds arrived at Suva, near the southeastern extremity of the largest island, which indicated by the circulation that the center was receding southward. According to newspaper reports, two hurricanes devastated the islands, one about the 21st and 22d of February and the other on the 1st and 2d of March. These are the four days on which, during 14 days of stormy weather with periods of abnormally heavy rainfall, the meteorological conditions were apparently most violent. The destruction to property, including buildings and cattle, and to such crops as breadfruits and sugarcane, as well as the loss of approximately 200 lives, was probably confined to the principal island, Viti Levu. Most of the loss of life was by drowning in the extraordinary floods produced on the eastern slopes of the island, where many villages were wholly destroyed.

While the gales did not exceed force 9 at Suva, according to the consular report, yet hurricane velocities occurred in various districts, expecially in the north and west, where the cyclonic force seems to have centered, and also at sea. In some localities both east and west of the principal mountain range the flood stages in the rivers were the highest of record. The heaviest rainfall reported occurred at Nandarivatu, on the western slope of the range, near Mount Victoria, where 84 inches fell in less than a week. The heavy precipitation occurred to the east of the storm center and quite apparently in the forward left-hand quadrant, as the cyclone seemingly moved southwestward during the occurrence of most of these excessive rains.

The lowest barometer reading reported was 28.70 inches, occurring at Lautoka, on the northwest of Viti Levu, at midnight of the 21st. Shipping was much hampered by the heavy seas, the high winds, and the thick weather, which prevented a landing, The steamship *Golden Harvest* occupied 15 days in making the trip of 1,500 miles between Brisbane and Fiji, and the steamship *Malake* spent three days during the 21st to 24th in steaming the 50 or 60 miles between the Fijian ports of Levuka and Suva, harbor lights being obscured by the blinding rain, and the ship also being driven off her course by the terrific winds and seas.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for March of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the March, 1930, means from the 11-year means for March (1920–1930), and the changes from the temperatures for the preceding month of February, 1930.

The chart shows the number of observations taken during the month of March, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea: The 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

March normally brings the turn of the season in the temperature of the surface water in the Caribbean Sea and the Straits of Florida, the first quarter showing, in both bodies of water, the lowest average temperatures of any winter quarter-month, the means for the 11 years in this quarter-month being 78.2° in the Caribbean Sea and 73.9° in the Straits of Florida.

The temperature rises noticeably during the last days of March. This effect has, in the majority of years for which observations are available, made March warmer than February, more than compensating for the downward trend of the average temperature, which persists until some days after the month begins.

The seasonal lag is thus between 70 and 80 days after the winter solstice, as compared with the 15 to 40 day lag of air temperatures along the island and continental coast lines of the region.

Reference to Table 3 will show that the temperatures rose markedly from the February values, which were close to normal, to rather high figures for March in both the Caribbean Sea and the Straits of Florida. The third quarter was, in the Caribbean, as warm as the mean for the corresponding part of April, with the abnormally high readings occurring principally within the western half of the sea and south of the twentieth parallel.

TABLE 1.—*Lengths of "Quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[1] In three cases, as indicated on the chart, the observations for small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for March (1919–1930)*

Year	Caribbean Sea: Number of observations	Caribbean Sea: Mean (°F.)	Straits of Florida: Number of observations	Straits of Florida: Mean (°F.)
1919 [1]	26	78.3	15	78.2
1920	139	78.9	20	72.2
1921	194	78.2	53	75.8
1922	170	78.7	75	75.9
1923	346	77.6	110	76.0
1924	318	78.3	84	73.5
1925	247	78.6	73	75.0
1926	434	79.2	129	73.9
1927	347	79.1	126	76.0
1928	360	79.0	106	74.7
1929	457	78.6	146	76.1
1930	531	78.9	149	75.8
Mean (1920–1930)		78.6		75.0

[1] Not used in computations because of insufficient data available.

TABLE 3.—*Mean sea-surface temperatures (°F), and number of observations, March, 1930*

Quarter	Period	Caribbean Sea: Number of observations	Caribbean Sea: Mean	Caribbean Sea: Departure from 11-year mean (1920-1930)	Caribbean Sea: Change from preceding month	Straits of Florida: Number of observations	Straits of Florida: Mean	Straits of Florida: Departure from 11-year mean (1920-1930)	Straits of Florida: Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	1-7	114	78.0			31	74.7		
II	8-15	145	78.8			38	76.8		
III	16-23	123	79.6			40	75.8		
IV	24-31	149	79.2			40	75.9		
Month		531	78.9	+0.3	+0.5	149	75.8	+0.8	+1.2

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, March, 1931

(For description of tables and charts, see REVIEW, January, p. 50)

Section	Temperature: Section average	Temperature: Departure from the normal	Monthly extremes: Station	Highest	Date	Monthly extremes: Station	Lowest	Date	Precipitation: Section average	Precipitation: Departure from the normal	Greatest monthly: Station	Amount	Least monthly: Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	49.9	−6.0	2 stations	78	[1] 19	Valley Head	22	4	3.80	−2.16	Seven Hills	7.26	Tuskegee	1.78
Arizona	53.4	+0.5	Le Sage	100	22	Alpine	−12	26	0.23	−0.85	Henry's Camp	1.66	29 stations	0.00
Arkansas	47.5	−5.1	Okay	85	13	Dutton	16	10	4.21	−0.47	Wynne	6.83	Portland	2.73
California	53.2	+2.6	Mecca	100	22	Ellery Lake	−2	29	1.47	−2.38	Crescent City	10.87	9 stations	0.00
Colorado	32.2	−2.4	3 stations	81	22	Spicer	−25	27	1.17	−0.21	La Veta Pass	4.37	Las Animas	0.18
Florida	59.5	−6.1	Fort Lauderdale	86	29	Mount Pleasant	26	5	5.23	+2.11	Garniers	9.25	Carrabelle	2.40
Georgia	51.2	−5.3	Quitman	84	27	Clayton	19	5	2.96	−2.02	Clayton	7.25	Goat Rock	1.46
Idaho	35.9	0.0	Glens Ferry	77	22	Felt	−20	6	2.40	+0.81	Roland	7.54	Ashton	0.20
Illinois	37.3	−3.5	Mascoutah	69	13	2 stations	12	11	2.75	−0.30	Anna	4.57	Hoopeston	1.68
Indiana	36.7	−4.0	Rome	68	23	Goshen	1	13	3.03	−0.72	Shoals	5.37	Noblesville	1.64
Iowa	34.9	+0.3	Baxter	64	13	Decorah	5	30	1.68	−0.08	Fairfield	4.18	Alton	0.15
Kansas	39.1	−4.6	St. Francis	85	18	Goodland	−3	27	2.41	+0.92	Trousdale	4.77	Irene	0.90
Kentucky	41.5	−4.8	Williamsburg	73	24	3 stations	18	[1] 3	3.68	−1.01	Quicksand	5.79	Cold Spring	2.11
Louisiana	54.3	−6.4	Melville	84	14	Robeline	25	10	4.15	−0.59	Pearl River	6.55	Logansport	1.46
Maryland-Delaware	39.3	−3.7	2 stations	65	25	2 stations	14	11	4.38	+0.95	Millsboro, Del	5.97	Picardy, Md	3.22
Michigan	30.2	+0.6	Ganges	59	23	Wolverine	−14	11	2.05	−0.12	Deer Park	3.75	St. Ignace	0.78
Minnesota	28.5	+2.2	Beardsley	63	20	2 stations	−12	15	1.23	+0.15	Roseau	2.12	Pigeon River Bridge.	0.21
Mississippi	51.2	−5.6	6 stations	80	[1] 14	Batesville	24	10	4.63	−1.14	Pontotoc	7.95	Lake	2.35
Missouri	39.5	−4.4	5 stations	70	[1] 13	Unionville	10	4	3.02	0.00	Poplar Bluff	6.03	Edgerton	1.23
Montana	32.7	+2.6	Billings	74	21	Adel (near)	−22	27	0.80	−0.12	2 stations	4.34	2 stations	T.
Nebraska	34.5	−1.4	Benkelman	78	22	Mullen	−14	27	1.74	+0.64	Curtis	5.25	Hull (near)	0.38
Nevada	42.1	+1.2	Las Vegas	92	22	San Jacinto	−3	17	0.48	−0.40	Lewers Ranch	2.80	3 stations	0.00
New England	34.7	+2.4	Adams, Mass	64	28	Pittsburg (a), N. H.	−14	3	3.78	+0.52	Falmouth, Mass	8.14	Bethlehem, N. H	0.72
New Jersey	39.2	+0.7	2 stations	64	[1] 25	Belleplain	12	14	4.14	+0.30	Chatham	6.06	Layton	2.60
New Mexico	40.5	−2.5	do	89	[1] 22	Selsor Ranch	−26	8	0.99	+0.13	Gallinas Planting Station.	3.86	3 stations	0.00
New York	33.8	+1.7	Mohonk Lake	68	27	North Lake	−3	3	2.27	−0.74	Cutchogue	6.96	Sperryville	0.52
North Carolina	44.4	−5.5	2 stations	77	14	Mount Mitchell	1	5	3.66	−0.54	Mount Mitchell	7.82	Marshall	1.28
North Dakota	25.7	+1.6	Portal	63	31	Towner	−24	26	0.94	+0.24	Bowman	2.33	Westhope	0.07
Ohio	36.2	−3.1	Ironton	66	24	Canfield	11	11	2.14	−1.28	2 stations	3.97	London	1.17
Oklahoma	45.6	−5.4	Hollis	85	12	Hooker	−2	31	3.08	+1.24	Buffalo	5.08	Kenton	1.02
Oregon	42.2	+1.4	2 stations	80	2	Lake	−3	7	4.06	+1.43	Valsetz	29.54	Lake	0.57
Pennsylvania	36.3	−1.4	Gettysburg	69	27	3 stations	10	[1] 3	2.96	−0.48	New Park	5.72	Montrose	0.70
South Carolina	48.8	−5.8	Garnett	78	[1] 14	Caesar's Head	18	5	2.98	−0.97	Crescent	5.29	Darlington	1.39
South Dakota	31.9	+0.3	Cedar View	72	22	Lead	−16	[1] 26	1.16	+0.11	Dumont	3.17	Onaka	0.21
Tennessee	41.1	−5.3	Clarksville	72	13	Elkmont	11	5	3.79	−1.55	Celina	5.44	Johnson City	1.28
Texas	52.7	−6.0	Mission	95	26	Miami	4	27	2.50	+0.42	Bon Wier	7.30	2 stations	T.
Utah	37.8	−0.4	St. George	85	21	Woodruff	−11	27	0.82	−0.71	Silver Lake	3.33	Escalanti	0.00
Virginia	40.7	−5.2	Diamond Springs	69	25	Burkes Garden	15	18	3.56	−0.10	Onley	5.90	Damascus	1.54
Washington	42.0	+1.1	Nespelem	79	12	Bumping Lake	6	4	5.96	+1.98	Big Four	29.94	Oroville	0.43
West Virginia	37.4	−5.3	Romney	68	27	Pickens	10	13	3.52	−0.26	Pickens	7.95	Upper Tract	1.90
Wisconsin	30.4	+1.1	3 stations	58	[1] 12	Downing	−18	1	1.73	−0.01	Racine	5.71	Chippewa P. K. Reservoir.	0.42
Wyoming	29.0	−0.6	Thermopolis	71	21	Foxpark	−33	6	1.04	−0.04	Bechler River	4.93	Dubois	0.10
Alaska (Feb.)	14.3	+6.9	Tree Point	53	3	Pilot Station	−43	27	2.27	+0.38	Ketchikan	16.15	Barrow	0.02
Hawaii	70.3	+1.0	Kaanapali	90	[1] 23	Volcano Observatory	46	6	3.98	−4.92	Kawainui (lower)	17.99	Launiupoko	0.00
Porto Rico	75.9	+2.6	Dorado	96	17	Jayuya	50	15	2.67	−0.91	Barros	9.40	Santa Isabel	0.13

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation: Thermometer above ground	Elevation: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity, Miles per hour	Wind: Maximum velocity, Direction	Wind: Maximum velocity, Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							36.4	+3.6										78	4.10	+0.7										6.5		
Eastport	76	67	85	29.82	29.91	−0.02	33.8	+4.9	50	23	38	21	7	30	21	32	28	80	2.80	−1.0	13	9,179	ne.	56	e.	9	8	0	23	7.7	15.1	0.0
Greenville, Me.	1,070	6	----	28.74	29.97	------	30.2	------	52	23	38	4	3	22	36	----	----	----	2.26	------	11	4,634	n.	23	------	5	7	7	17	----	17.8	----
Portland, Me.	103	82	117	29.80	29.93	−.03	36.6	+4.8	53	31	42	24	7	32	18	32	27	71	6.78	+2.9	11	6,425	n.	32	e.	8	12	4	15	5.8	10.1	0.0
Concord	289	70	79	29.57	29.90	−.10	35.7	+4.9	54	22	44	13	3	28	30	----	----	----	3.10	+0.1	9	4,232	n.	33	ne.	8	13	8	10	5.1	10.0	0.0
Burlington	403	11	48	29.48	29.94	−.06	32.6	+3.5	53	24	39	9	3	26	28	----	----	----	1.82	−0.2	11	5,015	n.	29	se.	8	5	6	20	7.4	10.1	T.
Northfield	876	12	60	28.97	29.95	−.05	30.3	+3.9	53	27	40	−1	3	21	38	27	25	84	1.90	−0.7	11	3,462	n.	22	n.	18	4	13	14	6.7	19.6	T.
Boston	125	106	165	29.71	29.88	−.09	39.3	+3.7	57	29	45	27	3	31	18	35	29	72	4.66	+1.1	12	6,608	nw.	32	ne.	25	8	11	12	6.1	7.3	0.0
Nantucket	12	14	90	29.82	29.83	−.15	37.8	+2.3	52	29	42	30	3	34	13	36	33	85	6.30	+2.6	13	13,227	ne.	59	ne.	4	7	8	16	7.1	12.3	0.0
Block Island	26	11	46	29.82	29.85	−.13	37.4	+2.0	50	29	42	28	14	33	14	35	32	84	4.08	+0.2	10	13,273	w.	48	n.	26	8	8	15	6.4	8.5	0.0
Providence	160	215	251	29.70	29.88	−.10	38.8	+3.1	53	21	45	26	3	32	23	34	30	75	4.14	+0.6	12	9,188	nw.	34	n.	26	10	8	13	5.7	10.2	0.0
Hartford	159	122	----	29.72	29.90	−.09	38.6	+3.6	59	21	45	23	3	32	25	----	----	----	4.26	+0.4	11	------	nw.	----	------	----	6	8	17	6.7	6.0	0.0
New Haven	106	74	153	29.77	29.89	−.10	39.0	+3.2	56	27	45	26	3	33	20	35	30	73	5.27	+1.2	12	7,436	n.	31	n.	26	7	11	13	6.3	6.3	0.0
Middle Atlantic States							40.1	−0.7										71	3.61	+0.1										7.2		
Albany	97	107	115	29.82	29.93	−.08	37.6	+4.9	57	24	44	18	3	31	28	32	26	67	1.48	−1.1	10	5,011	n.	26	ne.	26	8	10	13	6.3	4.7	0.0
Binghamton	871	10	84	28.97	29.92	−.10	34.7	+2.1	57	27	41	19	3	28	29	----	----	----	1.46	−1.2	13	4,526	nw.	21	se.	24	1	4	26	8.8	5.3	0.0
New York	314	414	454	29.55	29.90	−.10	40.5	+2.8	60	27	47	29	11	34	22	35	29	69	4.74	+1.1	11	11,640	nw.	51	nw.	5	4	8	19	7.6	1.0	0.0
Bellefonte	1,050	5	36	28.79	29.93	------	34.0	------	56	27	41	19	3	27	30	30	27	78	1.61	------	13	------	w.	----	------	----	0	7	24	8.8	4.7	0.0
Harrisburg	374	91	104	29.54	29.95	−.08	38.7	−0.2	57	23	44	25	3	33	20	34	27	66	3.72	+0.7	13	5,801	w.	24	w.	5	5	7	19	7.3	2.9	0.0
Philadelphia	114	123	367	29.79	29.92	−.10	42.3	+1.5	61	27	48	29	11	36	21	36	29	62	3.97	+0.6	12	10,656	nw.	37	nw.	5	3	9	19	7.5	0.8	0.0
Reading	325	81	98	29.57	29.93	------	39.4	−0.6	58	27	46	27	3	33	21	31	29	70	4.35	+0.8	11	5,510	w.	38	e.	8	7	9	15	7.1	3.2	0.0
Scranton	805	111	119	29.01	29.93	−.09	36.7	+1.0	60	27	43	22	3	31	28	32	28	74	2.20	−1.0	11	5,155	ne.	30	e.	8	3	8	20	7.5	3.2	0.0
Atlantic City	52	37	172	29.83	29.89	−.13	40.0	+1.4	57	29	45	27	11	35	21	36	32	75	5.19	+1.6	15	13,768	w.	54	e.	8	5	7	19	7.0	2.2	0.0
Cape May	17	13	49	------	------	------	40.5	−0.3	57	25	46	28	11	35	20	37	31	82	5.92	+2.2	16	------	nw.	----	------	----	4	11	16	----	7.3	0.0
Sandy Hook	22	10	55	29.86	29.87	------	39.6	------	54	27	44	30	11	35	16	35	31	74	3.91	−0.1	11	12,307	nw.	50	e.	8	7	7	17	6.3	0.1	0.0
Trenton	190	159	183	29.69	29.90	------	39.7	+0.6	59	27	46	26	3	33	22	34	29	70	3.24	−0.2	12	9,011	nw.	38	e.	8	4	8	19	7.4	0.2	0.0
Baltimore	123	100	215	29.79	29.92	−.11	41.9	−0.4	60	25	48	27	11	36	21	37	31	68	4.62	+0.9	11	8,638	nw.	35	ne.	8	6	9	16	6.8	10.0	0.0
Washington	112	62	85	29.81	29.94	−.10	41.3	−1.3	60	25	48	26	11	35	24	35	28	63	3.50	−0.2	14	6,158	nw.	30	nw.	10	5	12	14	6.6	T.	0.0
Cape Henry	18	8	54	29.87	29.89	------	42.8	−3.8	61	8	48	29	13	38	23	39	36	78	4.14	+0.3	13	11,066	nw.	44	n.	23	5	13	13	6.6	T.	0.0
Lynchburg	681	153	188	29.18	29.94	−.11	42.2	−5.1	61	26	49	30	21	35	27	36	30	65	3.75	+0.2	11	5,631	nw.	30	n.	19	7	5	19	6.7	4.3	0.0
Norfolk	91	170	205	29.82	29.92	−.11	44.2	−4.0	63	25	51	28	12	38	26	39	34	73	2.74	−1.0	13	10,046	n.	35	n.	3	5	8	18	6.9	T.	0.0
Richmond	144	11	52	29.78	29.94	−.10	42.3	−4.9	63	25	50	27	13	34	27	38	34	77	2.94	−0.7	10	6,396	nw.	29	w.	8	4	11	16	6.8	T.	0.0
Wytheville	2,304	49	55	27.50	29.94	−.11	36.7	−5.6	55	11	44	20	18	30	35	32	27	74	3.16	−0.3	12	5,151	nw.	26	w.	8	3	10	18	7.7	8.7	0.8
South Atlantic States							49.6	−4.1										68	3.51	−0.2										5.2		
Asheville	2,253	89	104	27.56	29.96	−.10	41.1	−3.8	65	13	50	21	5	32	39	34	28	68	2.59	−1.4	8	7,658	nw.	30	nw.	10	9	10	12	5.8	5.8	0.0
Charlotte	779	55	62	29.08	29.93	−.12	46.5	−3.9	68	14	56	28	12	37	31	39	32	63	4.41	+0.2	8	4,813	n.	29	sw.	8	10	10	11	5.4	4.7	0.0
Greensboro	886	6	56	28.97	29.94	------	42.6	------	68	14	53	21	11	32	33	36	32	73	3.53	------	12	6,787	n.	27	w.	9	5	12	14	6.4	3.0	0.0
Hatteras	11	5	50	29.88	29.89	−.15	47.6	−4.4	64	29	53	31	13	42	23	43	40	79	5.48	+1.2	12	11,615	nw.	52	nw.	3	9	10	12	5.6	T.	0.0
Raleigh	376	103	146	29.52	29.93	−.12	46.2	−4.0	68	14	55	28	11	38	28	40	33	66	3.15	−0.7	8	6,805	nw.	27	w.	9	9	7	15	6.1	0.5	0.0
Wilmington	78	81	91	29.86	29.95	−.10	50.1	−3.2	73	14	59	31	12	41	30	43	37	67	3.06	−0.1	11	5,419	w.	25	w.	25	13	9	9	5.0	0.1	0.0
Charleston	48	11	92	29.89	29.91	−.12	53.8	−3.6	75	15	61	35	5	46	21	47	41	69	2.88	−0.1	7	8,015	w.	37	se.	21	15	6	10	4.6	0.0	0.0
Columbia, S. C.	351	41	57	29.56	29.95	−.11	49.8	−5.4	70	14	59	32	5	41	29	42	35	63	2.96	−0.4	8	5,639	w.	28	sw.	8	11	8	12	5.3	0.3	0.0
Due West	711	10	55	29.19	29.98	------	47.2	------	68	14	57	27	5	37	32	----	----	----	3.01	------	8	7,476	w.	36	w.	8	9	10	12	5.7	0.8	0.0
Greenville, S. C.	1,039	139	146	28.82	29.93	------	46.8	−3.1	67	14	56	29	5	38	29	40	33	66	4.63	−0.5	10	7,064	ne.	36	ne.	31	12	10	9	5.0	T.	0.0
Augusta	182	62	77	29.74	29.94	−.12	51.6	−4.4	77	28	62	32	5	41	37	45	39	63	2.14	−2.0	6	4,786	nw.	27	w.	8	12	8	11	5.0	0.0	0.0
Savannah	65	150	194	29.87	29.94	−.12	54.8	−4.2	74	15	64	36	5	46	25	47	41	68	2.62	−0.4	7	9,494	w.	40	w.	8	17	5	9	4.1	0.0	0.0
Jacksonville	43	209	245	29.92	29.97	−.09	57.8	−4.8	78	28	66	38	10	49	25	50	44	67	4.69	+1.8	7	8,934	w.	60	se.	28	16	8	7	4.1	0.0	0.0
Florida Peninsula							64.5	−5.4										76	5.87	+3.8										4.8		
Key West	22	10	64	29.97	29.99	−.06	67.5	−5.1	82	1	73	53	11	62	24	62	59	78	4.44	+3.0	9	8,177	n.	49	w.	3	11	14	6	4.7	0.0	0.0
Miami	25	124	168	29.97	30.00	−.09	65.2	−5.0	82	29	72	45	10	58	27	59	55	74	6.10	+3.9	8	7,329	nw.	34	sw.	31	10	11	10	5.4	0.0	0.0
Tampa	35	79	197	29.96	30.00	−.07	60.8	−6.0	81	26	69	44	6	53	27	54	50	75	7.07	+4.6	8	7,985	nw.	36	e.	28	14	7	10	4.8	0.0	0.0
Titusville	44	5	----	29.94	29.99	------	60.8	------	80	15	71	39	10	51	32	----	----	----	4.91	------	8	------	w.	----	------	----	16	13	2	4.5	0.0	0.0
East Gulf States							52.2	−5.4										68	4.02	−1.2										4.9		
Atlanta	1,173	190	198	28.70	29.95	−.11	46.7	−5.3	68	13	55	29	10	38	26	39	32	62	3.46	−1.8	9	8,603	nw.	33	nw.	9	10	9	12	5.7	T.	0.0
Macon	370	78	87	29.56	29.96	−.10	50.8	−5.9	74	14	62	29	5	40	37	42	33	58	2.39	−2.6	9	5,242	nw.	28	se.	27	10	9	12	5.1	0.0	0.0
Thomasville	273	49	103	29.68	29.98	−.08	56.0	−4.2	80	27	66	34	10	46	30	47	40	64	3.73	−0.4	10	6,231	nw.	43	se.	28	10	11	10	4.9	0.0	0.0
Apalachicola	36	11	51	29.95	29.99	------	56.6	------	74	15	64	38	10	49	25	51	47	75	5.38	+1.3	9	6,984	nw.	51	e.	28	14	13	4	4.1	0.0	0.0
Pensacola	56	149	185	29.94	30.00	−.06	55.0	−5.3	70	25	61	37	4	49	23	50	47	79	4.80	0.0	10	10,422	w.	48	se.	21	12	10	9	4.7	0.0	0.0
Anniston	741	9	57	29.20	30.00	−.06	47.8	−4.7	72	24	59	25	5	37	34	----	----	----	3.31	−2.3	9	4,631	nw.	22	w.	8	13	7	11	5.1	T.	0.0
Birmingham	700	11	48	29.21	29.99	−.07	49.0	−6.4	71	24	59	28	10	39	30	41	35	67	2.78	−2.9	10	5,865	nw.	32	se.	27	11	9	11	5.1	0.1	0.0
Mobile	57	125	161	29.93	29.99	−.07	55.0	−4.7	74	19	63	37	4	47	27	49	44	74	6.35	+0.4	10	7,666	nw.	48	se.	27	12	9	10	4.8	0.0	0.0
Montgomery	223	100	112	29.74	30.00	−.05	52.4	−5.4	73	24	62	34	10	43	27	44	36	62	2.88	−3.1	11	5,210	nw.	27	w.	31	11	12	8	4.8	0.0	0.0
Corinth	469	6	----	------	------	------	47.5	------	69	13	58	26	10	38	35	----	----	----	4.14	------	12	------	se.	----	------	----	6	13	12	----	T.	0.0
Meridian	375	87	95	29.59	29.97	−.06	51.0	−6.1	72	19	60	31	5	42	34	43	36	64	3.73	−1.5	10	5,138	w.	28	se.	7	17	4	10	4.5	T.	0.0
Vicksburg	247	65	73	29.74	30.03	−.01	52.6	−5.9	77	19	62	34	9	43	33	44	38	65	4.45	−1.1	11	5,977	nw.	26	w.	7	14	7	10	4.9	0.0	0.0
New Orleans	53	76	84	29.95	30.01	−.03	57.5	−5.3	77	14	65	40	8	50	23	51	46	73	4.83	+0.1	10	4,937	w.	22	e.	30	13	7	11	5.1	0.0	0.0
West Gulf States							53.7	−5.5										68	2.85	+0.1										4.7		
Shreveport	249	77	93	29.71	30.02	.00	52.2	−6.1	79	23	62	32	28	42	32	47	43	78	3.34	−0.8	10	5,236	se.	21	w.	7	9	12	10	5.4	0.0	0.0
Bentonville	1,303	11	44	28.59	29.98	−.03	42.7	−4.6	66	13	51	23	28	34	31	----	----	----	3.14	------	7	4,562	nw.	24	s.	5	16	5	10	----	4.7	0.0
Fort Smith	457	79	94	29.51	30.00	−.01	47.2	−5.4	69	12	56	25	28	38	33	40	34	67	2.78	−0.2	9	7,376	e.	34	w.	7	8	9	14	6.2	T.	0.0
Little Rock	357	136	153	29.61	30.00	−.03	48.2	−4.8	70	23	56	31	29	40	29	41	33	61	4.47	−0.2	9	7,670	n.	38	w.	7	7	13	11	5.9	T.	0.0
Austin	605	136	148	29.38	30.02	------	55.8	−4.9	83	23	68	32	28	44	33	48	42	68	3.35	+1.0	8	7,273	s.	36	nw.	30	18	7	6	3.6	0.0	0.0
Brownsville	57	83	100	29.95	30.01	------	63.7	−4.5	82	20	72	40	9	55	32	59	51	72	1.19	−0.1	2	8,328	se.	33	se.	13	12	14	5	4.6	0.0	0.0
Corpus Christi	20	11	78	30.00	30.02	+.01	61.2	−3.8	79	30	70	36	9	53	34	55	50	71	2.45	+0.8	6	9,155	se.	32	nw.	30	11	11	9	4.8	0.0	0.0
Dallas	512	220	227	29.46	30.02	------	50.8	------	75	12	60	27	28	42	30	----	----	----	3.29	+0.4	8	10,948	w.	39	nw.	8	15	7	9	4.1	0.5	0.0
Fort Worth	670	106	114	29.29	30.01	+.03	51.8	−5.9	77	12	62	28	28	42	28	45	38	61	4.20	+1.9	9	7,010	nw.	28	nw.	27	10	9	12	5.6	T.	0.0
Galveston	54	106	114	30.00	30.06	+.05	56.0	−6.4	72	20	62	35	28	50	29	52	48	78	2.01	−0.7	8	8,841	se.	34	nw.	6	17	3	11	4.3	0.0	0.0
Groesbeck	461	11	56	29.52	30.02	------	52.0	------	80	23	62	30	28	42	33	----	----	----	2.92	+0.3	10	8,913	nw.	31	sw.	5	14	8	9	4.8	0.0	0.0
Houston	138	292	314	29.89	30.04	------	56.0	−7.3	78	23	65	33	28	47	29	----	----	----	2.45	−1.0	9	9,964	nw.	37	se.	20	13	9	9	4.5	0.0	0.0
Palestine	510	64	72	29.49	30.03	+.03	51.7	−7.4	81	23	62	28	28	42	30	45	39	68	3.39	−0.1	12	6,389	nw.	26	nw.	27	14	4	13	4.9	T.	0.0
Port Arthur	31	58	66	29.99	30.03	------	56.0	------	71	27	64	34	28	48	36	----	----	----	2.33	−0.9	7	6,767	s.	29	nw.	30	14	8	9	4.5	0.0	0.0
San Antonio	693	242	301	29.28	30.01	+.03	58.0	−1.8	84	23	69	32	7	47	29	49	41	58	2.06	+0.2	8	9,947	nw.	44	nw.	30	19	9	3	3.3	0.0	0.0
Taylor	571	38	51	29.45	30.06	+.07	54.6	−5.1	83	23	67	30	28	42	33	----	----	----	2.48	+0.4	9	6,967	nw.	29	sw.	23	17	9	5	3.8	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							39.9	−4.3										73	2.78	−1.4										7.6		
Chattanooga	762	190	215	29.15	29.97	−0.09	46.2	−5.0	67	24	55	29	5	38	30	39	31	60	4.61	−1.2	12	6,720	nw.	38	se.	27	9	11	11	5.6	0.2	0.0
Knoxville	995	102	111	28.89	29.96	−.10	44.6	−4.1	67	24	53	27	5	36	34	38	32	67	2.73	−2.3	10	5,589	sw.	30	sw.	8	6	9	16	6.5	0.4	0.0
Memphis	399	76	97	29.55	29.98	−.06	47.1	−5.2	67	13	54	33	4	40	24	41	34	65	3.23	−2.0	11	7,045	w.	37	sw.	7	8	6	17	6.4	T.	0.0
Nashville	546	168	191	29.40	30.00	−.05	44.2	−5.0	67	13	52	27	5	36	31	39	33	68	3.49	−1.6	12	7,686	nw.	32	w.	24	8	8	15	6.1	1.2	0.0
Lexington	989	193	230	28.91	30.00	−.05	37.8	−5.9	62	14	45	21	10	31	28	----	----	----	3.19	−1.1	11	9,022	w.	36	w.	25	5	8	18	6.8	3.9	0.0
Louisville	525	188	234	29.40	30.00	−.05	40.1	−5.3	65	14	47	27	11	33	22	36	31	72	2.83	−1.6	9	7,850	n.	35	sw.	7	5	7	19	7.4	2.4	0.0
Evansville	431	76	116	29.51	29.99	−.05	41.2	−4.7	63	13	48	28	2	34	25	37	32	74	3.55	−0.6	10	7,288	n.	35	w.	24	3	9	19	7.5	1.2	0.0
Indianapolis	822	194	230	29.06	29.97	−.07	36.5	−3.5	58	23	42	21	10	31	23	33	28	73	2.32	−1.6	13	8,536	nw.	30	nw.	9	4	5	22	7.9	6.8	0.0
Royal Center	736	11	55	29.16	29.98	------	34.2	------	57	23	40	18	12	28	31	----	----	----	2.26	−0.7	11	8,486	nw.	43	e.	7	2	5	24	8.4	9.2	0.0
Terre Haute	575	96	129	29.35	29.98	------	38.2	------	59	23	45	22	10	32	26	34	30	76	2.51	−1.2	12	6,690	nw.	29	sw.	28	5	6	20	7.5	6.2	0.0
Cincinnati	627	11	51	29.28	29.98	−.07	38.0	−2.9	58	23	45	21	2	31	25	34	30	79	1.97	−1.9	13	5,667	ne.	27	sw.	24	2	4	25	8.5	8.1	0.0
Columbus	822	216	230	29.07	29.97	−.07	37.3	−1.8	56	23	43	22	11	31	20	33	29	76	1.34	−2.2	16	7,804	nw.	37	sw.	24	0	5	26	8.6	5.3	0.0
Dayton	899	137	173	28.99	29.97	------	37.1	−3.4	57	23	43	24	12	32	24	33	30	77	2.51	−1.2	16	6,317	nw.	33	sw.	28	2	5	24	8.2	4.5	0.0
Elkins	1,947	59	67	27.87	29.99	−.06	33.9	−6.1	52	28	40	19	10	28	29	31	28	84	2.93	−0.9	19	4,206	w.	26	se.	7	0	4	27	9.4	16.1	0.0
Parkersburg	637	77	82	29.31	29.98	−.07	38.8	−4.0	59	24	45	24	10	33	26	34	30	75	2.60	−0.9	19	4,142	nw.	24	sw.	24	0	2	29	9.1	5.6	0.0
Pittsburgh	842	353	410	29.04	29.96	−.08	36.4	−3.2	59	27	42	20	11	31	22	32	29	78	2.48	−0.6	16	7,161	w.	30	e.	7	1	7	23	8.5	3.9	0.0
Lower Lake Region							31.2	+1.2										77	2.19	−0.5										7.9		
Buffalo	767	247	280	29.09	29.94	−.08	32.5	+1.4	51	24	37	20	10	28	18	30	27	80	3.30	+0.7	16	8,973	w.	40	w.	29	2	6	23	8.2	19.0	0.0
Canton	448	10	61	29.44	29.93	------	31.8	+4.1	57	24	39	4	2	24	30	----	----	----	0.86	−1.6	11	5,333	e.	37	e.	8	2	12	17	7.4	4.8	0.0
Ithaca	836	74	100	29.00	29.93	------	35.2	+3.4	57	27	42	21	15	29	27	31	27	76	2.16	−0.2	11	6,313	nw.	34	se.	24	2	9	20	8.1	15.4	0.0
Oswego	335	71	85	29.56	29.89	−.12	34.5	+3.3	54	24	39	24	15	30	23	32	28	76	1.76	−0.8	15	6,646	n.	27	w.	12	0	10	21	8.3	11.9	0.0
Rochester	523	86	102	29.37	29.96	−.06	35.0	+3.2	56	24	40	21	14	30	22	31	26	74	3.61	+0.8	13	5,671	w.	24	w.	12	5	6	20	7.7	21.4	0.0
Syracuse	596	65	79	29.28	29.94	−.08	36.2	+4.8	57	24	41	24	15	31	24	----	----	----	1.98	−1.0	15	4,746	w.	24	e.	8	4	9	18	7.5	4.3	0.0
Erie	714	130	166	29.17	29.96	−.06	33.9	+0.4	54	27	38	21	10	30	20	31	28	79	2.00	−0.6	13	8,068	nw.	41	se.	28	4	6	21	7.7	11.8	0.0
Cleveland	762	267	337	29.11	29.95	−.08	33.9	−0.7	60	28	38	19	10	30	22	31	27	77	1.51	−1.2	15	8,829	w.	46	se.	7	3	6	22	8.4	4.1	0.0
Sandusky	629	5	67	29.27	29.97	−.06	35.0	−0.1	57	28	40	21	11	30	23	----	----	----	2.16	−0.6	13	6,072	e.	25	ne.	7	2	6	23	8.4	6.9	0.0
Toledo	628	208	243	29.29	29.99	−.04	34.6	−0.7	55	28	40	19	11	30	23	31	26	73	2.27	−0.3	11	8,091	n.	43	ne.	7	5	3	23	7.9	9.4	0.0
Fort Wayne	856	100	119	29.03	29.98	------	34.0	−4.9	55	23	39	19	12	29	22	31	28	80	1.96	−1.3	12	6,968	nw.	31	nw.	9	3	4	24	8.4	11.5	0.0
Detroit	730	218	258	29.17	29.99	−.04	34.0	+0.6	55	28	39	19	10	29	24	31	28	81	2.67	+0.3	13	6,658	nw.	36	sw.	28	6	6	19	7.2	14.3	0.0
Upper Lake Region							30.5	+2.2										80	2.33	+0.2										7.5		
Alpena	609	13	92	29.35	30.03	.00	28.2	+2.7	42	22	34	13	14	22	21	26	23	81	2.13	+0.1	13	7,556	nw.	32	ne.	28	5	9	17	7.0	17.2	T.
Escanaba	612	54	60	29.40	30.09	+.05	28.0	+3.8	43	22	34	7	7	22	23	25	22	79	1.25	−0.6	5	7,829	n.	36	n.	8	3	10	18	7.5	8.9	1.0
Grand Haven	632	54	89	29.30	30.01	−.02	32.1	+0.4	55	23	38	16	12	27	27	30	27	84	2.53	+0.1	11	7,060	n.	33	n.	9	4	3	24	8.3	13.7	0.0
Grand Rapids	707	70	244	29.22	30.01	−.02	33.6	+0.2	55	23	39	22	12	28	25	30	26	77	1.94	−0.5	10	7,868	n.	39	n.	9	2	5	24	8.6	11.5	0.0
Houghton	668	64	99	29.38	30.13	+.09	27.4	+4.6	50	23	33	2	7	22	29	----	----	----	1.61	−0.4	9	6,149	n.	33	n.	28	5	5	21	7.9	14.1	T.
Lansing	878	6	88	29.02	29.98	------	31.9	−0.3	57	28	38	14	10	26	27	30	28	88	2.10	−0.2	15	5,972	nw.	25	nw.	9	3	7	21	8.1	14.4	0.0
Ludington	637	60	66	29.31	30.02	------	31.5	+1.4	48	23	36	18	7	27	19	29	26	82	3.01	+0.7	13	6,359	n.	31	nw.	9	4	7	20	7.4	15.9	0.0
Marquette	734	77	111	29.28	30.11	+.07	29.3	+4.5	49	23	34	13	7	25	18	27	24	80	2.61	+0.4	15	6,965	nw.	29	nw.	9	2	5	24	8.5	26.0	8.0
Port Huron	638	70	120	29.26	29.97	−.06	31.5	+1.1	52	28	36	18	10	27	18	29	26	85	2.57	+0.5	12	7,242	n.	30	nw.	9	3	5	23	8.1	17.2	0.0
Sault Sainte Marie	614	11	52	29.36	30.08	+.05	27.0	+5.4	48	23	33	6	10	21	27	24	20	79	1.15	−0.7	12	5,455	nw.	29	n.	9	10	6	15	5.7	11.1	1.3
Chicago	673	7	131	29.27	30.02	−.01	34.8	−0.5	53	23	39	21	10	31	21	31	27	74	3.33	+0.8	12	7,815	ne.	31	ne.	7	4	7	20	7.6	19.8	0.0
Green Bay	617	109	141	29.37	30.05	+.01	31.0	+2.4	52	23	37	13	1	25	21	28	24	79	1.71	−0.3	9	7,922	n.	48	ne.	28	4	5	22	8.2	14.9	6.5
Milwaukee	681	125	221	29.27	30.03	.00	33.7	+1.6	49	25	39	20	10	28	19	30	27	77	4.76	+2.3	13	9,226	n.	38	ne.	7	5	11	15	6.7	36.3	0.5
Duluth	1,133	5	47	28.89	30.16	+.10	27.5	+3.8	45	31	34	10	1	21	26	24	21	81	1.87	+0.3	10	8,649	ne.	32	ne.	26	10	6	15	6.0	13.5	0.0
North Dakota							26.1	+3.7										78	1.10	+0.3										6.5		
Moorhead	940	50	58	29.11	30.16	+.08	27.7	+5.0	48	20	37	2	15	18	29	24	20	75	0.81	−0.2	7	6,670	n.	24	n.	26	4	8	19	7.3	4.6	0.0
Bismarck	1,674	8	57	28.31	30.16	+.10	27.2	+3.0	50	21	36	−7	26	18	37	24	20	78	1.26	+0.4	6	6,009	n.	28	n.	26	9	9	13	6.1	4.4	0.0
Devils Lake	1,478	11	44	28.55	30.19	+.14	23.9	+4.1	47	22	33	−8	26	14	36	21	18	81	1.10	+0.3	10	7,167	ne.	37	ne.	25	7	9	15	6.6	3.3	T.
Ellendale	1,457	10	56	28.54	30.16	------	26.5	------	54	22	36	2	26	17	33	----	----	----	1.27	+0.4	6	9,934	ne.	41	ne.	26	7	7	17	6.9	4.3	T.
Grand Forks	833	12	67	------	------	------	26.0	------	47	31	35	0	27	17	27	22	----	----	1.04	------	9	------	nw.	37	e.	13	15	9	7	----	3.4	0.0
Williston	1,878	41	48	28.12	30.17	+.13	25.7	+2.8	60	31	36	−7	26	15	43	23	19	77	1.06	+0.4	6	5,033	se.	31	ne.	25	9	10	12	5.5	10.9	0.0
Upper Mississippi Valley							35.8	−0.3										72	2.20	−0.1										6.8		
Minneapolis	918	102	208	29.08	30.09	------	31.4	+1.8	51	25	38	12	1	25	27	----	----	----	1.49	+0.1	7	7,678	n.	32	n.	24	6	6	19	7.2	0.4	0.0
St. Paul	837	236	261	29.17	30.11	+.05	31.6	+2.5	49	12	38	12	1	25	26	----	----	----	1.56	+0.1	10	7,562	nw.	31	nw.	28	7	8	16	6.9	2.4	0.0
La Crosse	714	11	48	29.27	30.06	+.02	33.2	+1.7	54	12	40	13	1	26	30	29	24	74	1.79	+0.2	9	3,552	nw.	18	nw.	8	7	3	21	7.2	14.8	1.0
Madison	974	70	78	28.96	30.05	+.01	31.7	+1.1	53	23	38	15	1	26	22	28	24	77	2.35	+0.3	10	6,899	nw.	42	n.	28	7	6	18	7.1	21.0	3.0
Wausau	1,247	4	62	------	30.10	------	30.4	------	52	12	37	6	1	23	28	----	----	----	1.33	−0.4	9	4,812	n.	23	n.	28	10	6	15	----	10.8	T.
Charles City	1,015	10	51	28.97	30.09	+.04	33.8	+3.1	54	25	42	15	4	26	34	29	23	71	1.43	−0.3	4	4,962	se.	24	nw.	8	12	4	15	5.8	7.7	0.0
Davenport	606	71	79	29.35	30.03	.00	36.2	+0.1	56	22	43	20	4	29	24	31	26	70	2.87	+0.6	11	7,519	nw.	36	ne.	7	8	5	18	7.1	10.6	T.
Des Moines	861	5	99	29.13	30.06	+.02	36.0	+0.1	59	13	41	17	16	28	29	31	24	66	1.52	−0.3	8	7,420	nw.	33	n.	7	4	12	15	7.0	6.9	T.
Dubuque	700	81	96	29.28	30.05	+.01	34.4	+0.4	54	21	41	20	4	28	27	30	26	74	2.20	+0.2	9	5,005	n.	25	ne.	7	7	7	17	6.8	18.1	3.4
Keokuk	614	64	78	29.35	30.04	+.01	36.7	−2.2	58	22	44	21	4	30	26	32	26	70	2.18	−0.2	9	5,681	nw.	27	nw.	24	8	7	16	6.5	15.9	0.0
Cairo	359	87	93	29.60	29.99	−.07	43.4	−3.8	66	13	51	27	10	36	25	38	32	67	4.20	+0.4	8	7,121	n.	38	sw.	7	5	6	20	7.5	0.5	0.0
Peoria	609	11	45	29.34	30.02	−.01	36.7	−0.3	57	22	44	18	11	30	26	32	29	78	2.50	−0.2	10	5,480	nw.	26	ne.	7	8	7	16	6.3	10.3	0.0
Springfield, Ill	636	5	191	29.30	29.99	−.04	37.8	−2.4	59	13	45	24	4	31	23	34	30	77	2.79	−0.4	10	9,222	nw.	46	ne.	7	5	9	17	7.2	15.1	0.0
Hannibal	534	74	109	29.42	30.01	−.01	37.6	−3.4	61	13	44	23	10	31	30	----	----	----	2.36	−0.2	12	6,474	nw.	28	ne.	7	7	7	17	6.8	10.8	0.0
St. Louis	568	265	303	29.37	29.99	−.04	40.6	−3.2	68	13	47	26	8	34	28	35	29	69	2.39	−1.0	9	8,682	nw.	40	nw.	24	7	10	14	6.2	2.7	0.0
Missouri Valley							36.4	−1.1										69	1.83	0.0										6.2		
Columbia, Mo	784	6	84	29.15	30.01	−.02	38.4	−4.2	61	17	45	19	10	32	32	----	----	----	2.97	0.0	11	6,521	nw.	29	nw.	24	7	5	19	6.8	11.5	0.0
Kansas City	963	161	181	28.98	30.04	+.02	39.2	−3.5	66	17	46	23	9	32	32	34	28	70	2.35	−0.2	11	8,571	nw.	40	w.	24	10	7	14	5.8	14.1	0.0
St. Joseph	967	11	49	28.98	30.04	------	38.0	------	65	17	46	20	9	30	33	32	26	70	2.44	+0.4	10	7,148	nw.	38	nw.	24	13	4	14	5.5	12.5	T.
Springfield, Mo	1,324	98	104	28.57	30.00	−.02	40.8	−4.4	62	17	49	23	9	33	28	35	29	68	2.54	−0.8	11	8,037	nw.	31	w.	24	17	5	9	4.5	6.8	0.0
Iola	984	11	50	28.95	30.03	+.02	40.8	−3.7	68	17	50	19	28	32	34	----	----	----	2.56	−0.1	8	5,523	n.	24	nw.	23	9	7	15	6.3	6.5	0.0
Topeka	987	92	107	------	------	------	39.4	−3.2	70	17	48	20	9	31	34	----	----	----	1.94	−0.2	9	7,698	nw.	33	nw.	24	10	8	13	5.7	10.4	0.0
Lincoln	1,18	11	81	28.77	30.07	+.05	36.4	−1.1	60	22	45	14	9	28	34	32	26	72	1.39	+0.1	10	7,630	n.	38	w.	23	5	11	15	6.8	8.5	0.0
Omaha	1,10	115	122	28.86	30.08	+.04	36.4	−0.6	56	22	44	20	9	29	28	31	24	64	1.15	−0.2	10	6,742	nw.	32	nw.	24	11	6	14	6.0	8.9	0.0
Valentine	2,59	47	54	27.33	30.18	+.15	31.8	−0.5	68	22	42	−1	27	21	36	26	22	77	1.84	+0.8	9	6,144	n.	39	nw.	23	4	10	17	7.2	13.8	T.
Sioux City	1,13	94	164	28.84	30.09	+.04	35.2	+2.5	57	12	44	16	29	26	32	30	23	65	0.67	−0.5	7	8,875	nw.	38	nw.	24	6	10	15	6.8	3.0	0.0
Huron	1,30	59	74	28.70	30.14	+.08	31.9	+3.0	60	20	43	7	28	21	37	27	21	67	0.54	−0.4	9	6,840	n.	30	n.	23	9	12	10	6.8	5.0	0.0
Pierre	1,572	70	75	28.41	30.13	+.08	32.6	+1.1	64	22	43	3	27	22	35	27	22	69	2.22	+1.4	10	6,436	nw.	37	nw.	23	6	13	12	6.2	18.9	T.
Yankton	1,233	49	57	28.77	30.13	+.08	34.4	+1.2	59	17	44	12	28	25	35	----	----	----	1.14	−0.1	6	6,022	nw.	29	nw.	23	6	9	16	6.5	7.0	T.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1931*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							32.5	+1.2										67	1.01	0.0										6.4		
Billings	3,140	5	----	------	------	------	36.0	------	74	21	52	0	27	20	54	----	----	----	0.60	------	9	------	nw.	----	------	----	4	11	16	----	2.5	0.0
Havre	2,505	11	67	27.41	30.12	+0.12	31.6	+4.5	62	21	43	−4	26	20	35	27	22	71	0.82	+0.3	10	6,247	sw.	27	w.	3	2	18	11	6.5	9.4	0.0
Helena	4,124	89	113	25.82	30.10	+.09	35.8	+3.4	65	15	46	−5	27	26	37	28	18	51	0.32	−0.5	8	5,889	sw.	30	w.	4	0	13	18	7.8	2.0	0.0
Kalispell	2,973	48	56	26.98	30.10	+.11	35.7	+2.8	59	21	44	5	26	28	30	32	27	75	0.93	0.0	15	3,565	nw.	27	w.	3	4	6	21	7.4	4.7	0.0
Miles City	2,371	48	55	27.54	30.16	+.14	34.0	+5.4	65	15	45	0	26	23	44	29	23	67	0.34	−0.5	9	4,895	s.	30	nw.	19	7	11	13	6.2	1.4	0.0
Rapid City	3,259	50	58	26.64	30.16	+.15	31.4	−1.2	62	16	42	−5	26	21	51	27	21	71	1.15	+0.2	11	6,134	n.	38	nw.	23	8	11	12	6.1	7.9	2.1
Cheyenne	6,088	84	101	23.96	30.09	+.13	29.8	−3.3	56	16	40	−8	27	20	38	25	18	63	1.16	+0.1	13	10,669	w.	46	w.	22	10	5	16	6.2	15.7	T.
Lander	5,372	60	68	24.64	30.10	+.11	33.1	+0.7	67	21	46	−7	27	20	38	26	18	60	0.85	−0.3	5	3,852	sw.	39	sw.	9	13	13	5	4.5	8.5	0.1
Sheridan	3,790	10	47	26.13	30.13	------	32.2	------	67	21	44	−3	27	20	40	27	21	68	1.88	+0.7	11	3,534	nw.	32	nw.	19	7	8	16	6.5	5.9	0.0
Yellowstone Park	6,241	11	48	------	30.17	+.15	26.8	+0.3	53	21	36	−4	6	17	32	----	----	68	0.80	−0.9	13	6,320	sw.	30	nw.	25	2	8	21	----	11.3	0.0
North Platte	2,821	11	51	27.09	30.09	+.09	34.6	−2.0	69	16	46	0	26	23	40	29	24	74	1.81	+1.0	8	5,488	n.	34	nw.	23	7	12	12	6.4	13.2	2.5
Middle Slope							39.3	−4.0										65	1.84	+0.2										5.7		
Denver	5,292	106	113	24.71	30.07	+.12	36.6	−2.7	68	22	47	−2	27	26	36	29	20	56	1.00	0.0	14	5,535	s.	38	nw.	26	5	15	11	6.2	19.0	0.0
Pueblo	4,685	80	86	25.28	30.04	+.12	38.2	−3.4	72	22	51	10	27	25	45	31	21	55	0.41	−0.2	8	4,688	nw.	38	w.	22	13	12	6	4.9	2.4	0.0
Concordia	1,392	50	58	28.58	30.10	+.09	37.0	−4.0	62	12	47	14	28	28	37	32	28	74	1.38	+0.2	10	6,395	nw.	38	nw.	23	10	7	14	6.0	7.6	T.
Dodge City	2,509	11	51	27.43	30.10	+.13	37.9	−4.9	73	12	50	6	27	26	41	32	27	73	2.83	+1.9	10	7,267	nw.	27	nw.	5	12	7	12	5.4	12.1	1.0
Wichita	1,358	139	158	28.56	30.03	+.04	41.1	−4.0	70	12	50	14	28	32	36	36	30	69	2.52	+0.8	8	8,585	n.	38	sw.	12	11	5	15	5.9	5.0	0.0
Broken Arrow	765	11	56	29.18	30.01	------	44.5	------	69	18	54	19	28	35	33	----	----	----	1.65	−2.2	8	10,535	nw.	42	nw.	7	7	9	15	6.4	1.5	0.0
Oklahoma City	1,214	10	47	28.72	30.02	+.04	45.0	−5.0	76	12	55	16	28	35	36	38	30	64	3.06	+1.1	9	8,064	n.	28	nw.	7	14	7	10	5.3	2.2	0.0
Southern Slope							49.2	−5.4										58	0.96	+0.1										4.2		
Abilene	1,738	10	52	28.20	30.03	+.07	49.9	−6.6	80	22	63	19	27	37	38	41	33	60	1.12	−0.2	8	7,758	s.	31	s.	12	11	10	10	5.0	0.4	0.0
Amarillo	3,676	10	49	26.26	30.04	+.09	42.0	−4.9	80	22	54	7	27	30	41	34	26	61	1.69	+1.0	7	7,282	nw.	27	se.	25	13	8	10	4.7	15.0	0.0
Del Rio	944	64	71	28.99	29.99	+.04	57.2	−6.3	87	23	70	30	9	45	38	49	42	63	0.66	−0.1	3	6,633	se.	37	n.	30	16	12	3	3.4	0.0	0.0
Roswell	3,566	75	85	26.36	29.99	+.09	47.5	−3.8	85	22	64	16	27	32	51	37	24	47	0.38	−0.4	4	5,621	s.	42	nw.	19	17	10	4	3.6	1.0	0.0
Southern Plateau							51.9	+1.2										40	0.33	−0.2										2.6		
El Paso	3,778	152	175	26.17	29.96	+.08	54.6	−1.2	82	22	67	28	7	42	39	40	21	33	0.38	0.0	3	7,226	w.	44	w.	25	22	8	1	2.2	0.0	0.0
Santa Fe	7,013	38	53	23.19	29.99	+.10	36.2	−3.5	67	22	48	6	27	25	32	28	17	50	1.18	+0.4	9	4,513	n.	29	ne.	19	15	8	8	4.3	12.2	0.0
Flagstaff	6,907	10	59	23.32	29.94	+.03	38.6	+2.7	68	21	54	11	9	23	45	31	----	57	0.25	------	1	6,151	nw.	28	ne.	30	13	18	0	----	T.	0.0
Phoenix	1,108	10	107	28.80	29.95	+.04	62.8	+2.1	91	22	78	34	7	48	37	47	28	31	0.07	−0.6	1	3,732	e.	24	sw.	25	22	6	3	2.3	0.0	0.0
Yuma	141	9	54	29.83	29.98	+.04	66.4	+2.3	97	22	82	36	7	50	42	50	30	31	0.00	−0.3	0	4,231	n.	26	nw.	25	25	4	2	1.5	0.0	0.0
Independence	3,957	6	27	26.02	30.06	+.12	53.0	+4.5	81	31	69	24	6	37	42	38	----	----	T.	−0.5	0	------	nw.	----	------	----	22	8	1	----	0.0	0.0
Middle Plateau							41.1	+0.2										48	0.54	−0.5										4.7		
Reno	4,532	74	81	25.53	30.10	+.12	44.2	+3.2	72	20	58	16	6	30	42	36	25	50	0.08	−0.7	3	4,080	w.	35	se.	11	15	12	4	4.0	0.0	0.0
Tonopah	6,090	12	20	------	------	------	42.6	------	70	21	53	16	6	32	29	33	23	49	0.16	------	4	------	nw.	----	------	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.70	30.13	+.12	40.8	+0.8	71	31	56	8	6	26	44	33	20	48	0.25	−0.7	5	5,237	sw.	27	nw.	24	12	9	10	4.9	T.	0.0
Modena	5,473	10	43	24.64	30.03	+.07	38.9	+0.7	72	21	54	10	27	23	42	30	17	46	0.59	−0.4	3	6,795	w.	34	nw.	18	13	11	7	4.4	4.8	0.0
Salt Lake City	4,360	163	203	25.68	30.11	+.13	41.4	−0.3	70	21	50	19	27	32	28	34	24	52	1.14	−0.8	7	4,842	nw.	30	nw.	22	11	10	10	5.3	8.7	0.0
Grand Junction	4,602	60	68	25.39	30.01	+.07	40.2	−3.4	67	22	53	16	27	28	38	32	19	46	0.63	−0.1	6	3,600	nw.	26	w.	22	11	11	9	4.8	2.5	0.0
Northern Plateau							42.4	+0.6										63	2.23	+1.1										6.8		
Baker	3,471	48	53	26.53	30.17	+.14	38.4	+0.8	60	20	48	19	6	29	28	34	30	75	1.93	+0.8	14	4,129	se.	21	nw.	25	6	6	19	6.7	4.5	0.0
Boise	2,739	79	87	27.27	30.17	+.14	43.4	+0.7	65	15	53	23	7	34	31	37	28	56	2.49	+1.1	12	4,201	se.	21	se.	8	8	6	17	6.5	1.3	0.0
Lewiston	757	40	48	29.32	30.15	+.12	45.7	+0.3	66	20	55	25	7	36	34	----	----	----	4.07	+2.9	16	2,623	e.	26	nw.	3	5	8	18	7.0	0.1	0.0
Pocatello	4,477	60	68	25.54	30.14	+.13	36.5	−0.9	65	21	46	12	1	26	34	31	23	60	0.81	−0.5	9	6,120	se.	34	sw.	22	5	16	10	5.8	5.6	0.0
Spokane	1,929	101	110	28.04	30.12	+.11	41.6	+1.9	58	21	49	21	26	34	27	37	31	70	1.52	+0.3	14	4,770	s.	21	sw.	18	7	5	19	7.3	0.5	0.0
Walla Walla	991	57	65	29.04	30.12	+.10	46.6	+0.5	64	1	55	25	27	39	27	41	34	63	3.70	+2.1	15	3,448	s.	22	w.	18	5	9	17	7.2	3.0	0.0
Yakima	1,076	58	67	28.95	30.11	------	44.8	+0.7	66	21	55	23	6	35	32	38	28	56	1.11	+0.7	7	3,334	nw.	25	nw.	3	5	8	18	6.9	T.	0.0
North Pacific Coast Region							47.5	+2.3										76	5.40	+1.5										7.4		
North Head	211	11	56	29.88	30.12	+.11	47.3	+2.1	62	2	52	36	27	43	17	45	42	83	9.11	+3.6	23	12,856	s.	60	s.	19	5	11	15	6.8	T.	0.0
Port Angeles	29	8	53	------	30.08	------	44.5	------	59	19	51	32	6	38	18	----	----	----	1.74	−0.5	17	4,016	s.	30	w.	24	3	11	17	----	0.0	0.0
Seattle	125	215	250	29.96	30.09	+.10	47.1	+2.2	67	2	53	32	5	41	23	43	38	74	4.37	+1.3	21	6,970	s.	43	sw.	21	3	11	17	7.3	T.	0.0
Tacoma	194	172	201	29.88	30.10	+.10	46.6	+2.4	67	2	53	29	5	40	23	----	----	----	5.41	+1.9	21	5,738	s.	33	sw.	21	3	8	20	7.5	T.	0.0
Tatoosh Island	86	9	53	29.96	30.06	+.10	46.2	+3.3	55	7	50	34	28	43	12	44	41	84	9.73	+1.9	24	12,219	e.	51	e.	27	4	6	21	7.6	T.	0.0
Medford	1,329	29	58	28.72	30.14	------	48.0	------	71	2	60	22	5	36	41	43	36	69	1.16	−0.5	16	------	nw.	30	n.	3	7	8	16	6.8	0.0	0.0
Portland, Oreg	153	68	106	29.97	30.13	+.11	48.8	+1.9	65	2	56	33	5	42	26	45	40	74	8.12	+4.2	20	4,375	sw.	26	w.	21	3	1	27	8.5	T.	0.0
Roseburg	510	75	99	29.61	30.16	+.12	48.8	+1.7	71	2	58	28	6	40	38	45	40	74	3.58	+0.3	18	2,787	s.	21	sw.	31	4	7	20	7.3	0.0	0.0
Middle Pacific Coast Region							56.5	+3.7										68	1.42	−2.0										4.6		
Eureka	62	73	89	30.12	30.19	+.13	51.1	+2.8	66	6	57	36	5	45	26	48	45	81	3.35	−1.9	14	5,054	se.	31	n.	4	8	8	15	6.2	0.0	0.0
Red Bluff	330	5	58	29.75	30.11	+.07	58.0	+4.4	82	2	70	36	6	46	37	48	38	53	0.38	−2.9	7	4,648	nw.	24	se.	11	9	14	8	5.1	0.0	0.0
Sacramento	69	106	117	30.04	30.11	+.08	57.7	+3.4	79	31	69	38	7	47	32	52	46	69	1.14	−1.4	6	4,951	s.	24	nw.	26	20	8	3	2.8	0.0	0.0
San Francisco	155	208	243	29.96	30.13	+.07	59.0	+4.8	76	2	66	48	29	52	23	51	45	67	1.68	−1.5	7	4,412	w.	25	nw.	28	9	15	7	4.9	0.0	0.0
San Jose	141	12	110	29.98	30.13	------	56.6	+2.9	78	23	69	37	29	44	35	----	----	----	0.54	−2.1	4	3,909	nw.	23	nw.	25	11	16	4	4.2	0.0	0.0
South Pacific Coast Region							62.2	+5.8										56	0.18	−1.9										3.3		
Fresno	327	89	98	29.74	30.10	+.09	58.6	+3.6	81	21	71	40	26	46	31	50	41	60	0.48	−1.1	3	4,381	nw.	23	nw.	25	18	10	3	3.7	0.0	0.0
Los Angeles	338	159	191	29.67	30.03	+.01	66.0	+8.5	93	21	76	49	7	56	28	52	39	45	T.	−2.8	0	3,713	ne.	22	nw.	25	19	9	3	2.6	0.0	0.0
San Diego	87	62	70	29.93	30.02	.00	61.9	+5.2	90	21	71	45	7	53	31	53	47	64	0.06	−1.7	2	3,768	nw.	20	w.	24	19	6	0	3.7	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.88	29.97	------	78.2	+2.8	91	18	84	69	9	72	19	----	----	----	2.54	−0.6	9	6,462	c.	27	e.	14	6	21	4	5.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	------	29.84	------	82.8	+1.6	94	25	91	72	11	75	20	----	----	[1]76	0.70	0.0	----	6,968	n.	26	n.	13	2	21	8	6.3	0.0	0.0
Cristobal	36	0	97	------	29.86	------	82.7	+1.2	88	29	86	75	9	79	11	76	74	[1]77	4.48	+2.9	----	9,523	n.	28	nw.	3	2	17	12	6.6	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]29.52	[2]30.07	------	8.0	------	46	28	22	−28	14	−6	42	9	0	58	0.15	------	2	2,157	n.	20	ne.	12	19	2	10	3.8	2.1	5.8
Juneau	80	11	50	[2]29.87	[2]29.96	------	32.8	------	52	27	38	9	13	28	21	30	23	67	3.36	------	18	5,152	s.	38	e.	8	7	7	17	6.6	4.2	0.0
Hawaiian Islands																																
Honolulu	38	80	100	[2]30.02	[2]30.06	------	72.4	+1.0	80	29	77	63	1	68	13	66	62	72	0.94	−2.3	9	5,001	c.	26	ne.	31	13	14	4	4.2	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meterological Service, March, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Station, departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				31.8		36.9	26.7	43	18	2.57		4.3
Sydney, C. B. I.	48	29.87	29.92	+0.04	32.3	+6.1	37.4	27.3	52	16	5.66	+0.73	44.0
Halifax, N. S.	88	29.76	29.87	−.07	34.7	+5.7	39.6	29.8	50	25	4.09	−1.37	13.9
Yarmouth, N. S.	65	29.73	29.80	−.15	35.7	+4.9	41.5	29.9	56	23	4.24	−0.76	19.0
Charlottetown, P. E. I.	38	29.82	29.86	−.04	31.5	+6.1	36.0	27.0	45	14	2.64	−0.57	23.2
Chatham, N. B.	28	29.86	29.89	−.01	31.1	+8.1	38.8	23.5	52	5	2.12	−1.35	13.8
Father Point, Que.	20	29.95	29.97	+.07	30.0	+9.7	39.8	20.3	54	−14	0.24	−2.49	1.1
Quebec, Que.	296	29.64	29.98	+.02	31.5	+10.3	36.5	26.5	44	6	1.80	−1.46	16.9
Doucet, Que.	1,236				22.5		33.2	11.9	52	−12	0.86		8.5
Montreal, Que.	187	29.72	29.94	−.06	33.9	+10.1	39.1	28.7	51	14	1.62	−2.17	8.4
Ottawa, Ont.	236	29.68	29.96	−.05	34.0	+12.5	42.1	25.9	55	8	1.46	−1.26	7.5
Kingston, Ont.	285	29.62	29.94	−.07	34.2	+8.6	40.1	28.3	52	14	1.72	−0.92	8.4
Toronto, Ont.	379	29.54	29.97	−.05	33.4	+6.1	38.8	28.1	48	19	2.81	+0.17	17.2
Cochrane, Ont.	930				19.0		27.6	10.5	49	−9	1.21		12.1
White River, Ont.	1,244	28.75	30.12	+.09	18.6	+6.4	29.6	7.7	47	−20	0.84	−0.54	7.4
London, Ont.	808				32.3		38.6	26.0	51	17	2.16		14.0
Southampton, Ont.	656	29.25	29.98	−.05	29.4	+4.7	35.5	23.3	46	11	2.62	−0.03	19.9
Parry Sound, Ont.	688	29.26	29.97	−.05	28.5	+7.4	35.4	21.7	46	8	3.02	+0.79	20.1
Port Arthur, Ont.	644	29.44	30.18	+.13	25.3	+8.5	32.6	18.1	40	4	0.30	−0.67	2.8
Winnipeg, Man.	760	29.38	30.26	+.17	19.9	+7.6	27.8	12.0	42	−9	0.89	−0.14	7.0
Minnedosa, Man.	1,690	28.33	30.23	+.17	18.5	+6.0	29.5	7.5	44	−15	0.82	+0.17	8.2
Le Pas, Man.	860				12.5		24.0	1.0	43	−29	1.17		11.7
Qu'Appelle, Sask.	2,115	27.82	30.16	+.12	20.7	+5.8	30.1	11.2	57	−19	1.02	+0.25	9.8
Moose Jaw, Sask.	1,759				24.0		34.9	13.1	63	−15	0.98		8.6
Swift Current, Sask.	2,392	27.47	30.08	+.06	27.4	+5.4	38.5	16.2	63	−11	0.66	−0.15	4.9
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.60	30.25	+.17	18.5	+6.5	28.4	8.6	52	−27	0.88	+0.11	8.8
Battleford, Sask.	1,592	28.38	30.21	+.15	21.1	+8.0	31.5	10.6	60	−28	0.25	−0.21	2.5
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.81	30.07	+.10	45.4	+3.5	50.3	40.5	57	34	2.40	−0.72	T.
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Medicine Hat, Alb.	2,144	27.46	29.75	−.30	34.8	+23.6	46.7	23.0	59	10	0.00	−0.67	0.0
Banff, Alb.	4,521	25.30	30.01	+.03	25.9	+6.7	36.4	15.4	42	−5	0.45	−0.47	3.5
Edmonton, Alb.	2,150	27.54	29.86	−.16	31.7	+23.4	40.9	22.6	50	6	T.	−0.67	T.
Kamloops, B. C.	1,262	28.75	30.08	+.12	33.3	+5.0	37.8	28.7	52	13	0.43	−0.36	3.7
Esteven Point, B. C.	20				42.3		48.4	36.2	53	29	12.21		0.0
Prince Rupert, B. C.	170				39.7		43.6	35.9	47	32	8.80		T.

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A FIVE-YEAR RECORD OF LIGHTNING STORMS AND FOREST FIRES

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According to the records compiled by the supervisors of the national forests in the northern Rocky Mountain region, lightning has been responsible for a greater number of fires, more burned area, more damage, and more expense of suppression in this territory than all other causes of forest fires combined. Smokers, campers, brush burners, incendiarists, lumbering operations, and railroads combined start annually an average of 379 fires on these 23,000,000 acres of Federal forest land, but lightning is credited with an annual average of 824 fires during the 10-year period, 1919 to 1928. In 1926, which is accepted as one of the worst seasons for lightning fires, 311,607 acres of Federal, State, and private forest land in Idaho and Montana were burned over by fires started by lightning. The damage on this area was evaluated at $3,572,000, while the Federal Government alone spent approximately $948,000 for fire suppression.

These conditions have long been recognized as one of the major impediments to successful lumbering and forestry. As lumbering, which must depend in the future upon forestry, is one of the basic industries in this section of the country the economic importance of lightning storms is obvious. It is apparent that no industry subjected to such a chance of loss as has been indicated can operate as cheaply and efficiently as it could if the danger were fully understood and at least partially controlled.

Early in 1922 the Northern Rocky Mountain Forest Experiment Station commenced an investigation of lightning storms, working in cooperation with the Forest Service administrative organization, which had studied the occurrence of lightning-caused forest fires ever since the national forests were created. The administrative study had localized the danger both in time and by area, but it had not attempted to investigate the storms which are the causes of these fires. The research project, initiated in 1922, has been conducted for the purpose of assembling more and better information concerning the occurrence and characteristics of these storms which cause so much loss and expense.

As Morrell has pointed out (**11**) [1] the possibility of improving forest protection lies chiefly in reaching forest fires quickly and attacking them before they get large, with an adequate and properly equipped crew of men. Forest fires can be attacked with speed if they are few in number, or even when numerous, if the forest protective organization has a reasonably definite warning that such fires are probable. If warnings are available, men engaged on other work can be moved to locations more strategic for fire suppression, and additional men can be hired specifically for such an emergency. But when a single national forest of 600,000 acres, such as the Kaniksu in northern Idaho, is visited without any warning by lightning storms, that in one day start over 150 forest fires, as occurred on July 12, 1926, no forest protective organization is able to expand fast enough to cope with the situation. Under such conditions several fires are certain to be left without attention long enough for them to become so large that they spread as conflagrations through the crowns of the trees. One such crown fire often burns over more area, destroys more timber, and, after it drops to a ground fire and becomes approachable, often costs more for its suppression than a hundred or even a thousand other forest fires which are reached and extinguished before they have an opportunity to attain such momentum.

Such occurrences make very clear the importance and profitable application of warnings of lightning storms, especially if the warnings could be made available two or three days in advance, and could cover not only storm occurrences but also storm fire-starting probabilities. With such warnings action could be taken that would in nearly all cases reduce lightning fire damage and expense to a very satisfactory minimum. Even at present, with the weather predictions limited to a period of 36 hours and with no indications contained in the forecasts concerning the fire-starting characteristics of the storms, considerable progress is being made. Present investigations have contributed materially toward more accurate forecasts by obtaining more detailed records of storm occurrence. They have also found (**5**) that the types of storms which commonly start many fires can be distinguished from the types which do not start many fires. Furthermore, methods have been developed for measuring forest inflammability so that the danger of ignition and rapid spread can now be determined as a basis for administrative action (**6**).

The data herewith presented add to previously published information on lightning storms in this region largely through the increase in evidence on which the deductions are based. Some of the conclusions previously stated must now be slightly modified, but many are greatly strengthened by these 14,754 reports covering a 5-year period, as compared to the 3,800 reports for two years used as a basis for the first report. Some new aspects of the situation are also apparent in this greater volume of data.

[1] The **boldface** figures in parentheses refer to literature cited.

OCCURENCE OF STORMS

One of the outstanding discoveries resulting from this study is the knowledge that lightning storms are far more frequent in the forested sections of this region than previous records, largely obtained at low-elevation non-forest stations, had indicated. The present records, which are most complete for July and August, less complete for June and September, and fail entirely to cover the other eight months of each year, give for the region as a whole an average of 88 thunderstorm days each season, for the five years studied, as follows: 1924, 85; 1925, 95; 1926, 83; 1927, 87; and 1928, 88 days. For this same region Alexander's compilation, (2) which is quoted by most meteorological authorities, records only 10 to 30 thunderstorm days per year at individual Weather Bureau stations of the first order.[2]

FIG. I
MAP OF THUNDERSTORM OCCURRENCE.

AVERAGE NUMBER OF THUNDERSTORM DAYS EACH SUMMER, FOR GROUPS OF NATIONAL FORESTS, BASED ON RECORDS 1924-1928 INCLUSIVE. FOR NORTHERN IDAHO AND WESTERN MONTANA AS A REGION THESE DATA INDICATE AN AVERAGE OF AT LEAST 88 THUNDERSTORM DAYS PER YEAR.

This large increase in storm occurrence, indicated by the Forest Service data, is partly explained by the fact that the region has been treated as a unit, whereas Alexander's summary considers each observation station as a unit. Compilation for relatively large areas is justified, however, by the fact that fire-protection work is administered by Federal and State officials for areas seldom less than a hundred thousand acres and usually comprising many millions of acres. Weather forecasts also are usually worded to apply to large areas, half a State or more, and consequently must be based upon and should be rated according to the records of many stations. In this report relatively large areas are consequently treated as units.

Another important reason why the present summary shows more thunderstorm days than other records is the recognized more frequent occurrence of lightning storms over forested, mountainous areas, in contrast to their frequency over low elevation, valley or plains stations such as Spokane, Kalispell, Helena, Lewiston, etc., where the regular Weather Bureau observations are made.

The large number of thunderstorm days reported is also explained by the fact that the Forest Service observers used in this study consisted largely of the lookout men stationed on 270 or more high mountain tops continually scanning great areas and wide horizons for the streamers of smoke that locate forest fires. From these high points it is almost impossible for a thunderstorm to occur within 30 or 40 miles of a station without being seen or heard by the observer. It is probable that few, if any, storms escape detection during July and August, when these observatories are all occupied.

A fourth reason why the present data show more storm days than indicated by other sources of information may be that thunderstorms have been more frequent during the past few years. Such is the local opinion, but the lookout-station records do not cover a sufficient number of years to give either support or denial to this belief.

When the regional data obtained in this study are subdivided into smaller units, such as groups of national forests, a marked reduction in thunderstorm frequency is shown; yet even the totals surpass those based on observations at low-elevation stations largely outside the forests. The frequency for these small groups of forests is shown by Figure 1; and Table 1 permits comparison of these figures with those resulting from carrying the subdivision down to individual national forests.

TABLE 1.—*Relation of number of thunderstorm days to number of lightning fires per 100,000 acres for individual forests and forest groups in the northern Rocky Mountain Region*

Group and forest	Thunderstorm days, by years [1]						Fires per 100,000 acres annually
	1924	1925	1926	1927	1928	Average	
							Average number
Group I:							
Beaverhead	41	61	27	45	41	43	0.3
Deerlodge	------	------	------	------	------	------	.8
Helena	21	29	32	33	32	29	1.2
Average	------	------	------	------	------	[2] 56	1.0
Group II:							
Bitterroot	23	36	22	34	25	28	2.6
Lewis and Clark	15	36	32	39	19	28	.2
Missoula	23	31	28	44	39	33	1.7
Average	------	------	------	------	------	[2] 43	2.0
Group III:							
Blackfeet	15	20	28	35	36	27	6.8
Cabinet	9	27	24	44	40	29	4.7
Flathead	26	25	33	49	54	37	5.0
Kootenai	14	30	41	43	40	34	9.1
Lolo	20	41	34	42	44	36	3.5
Pend Oreille	20	24	26	37	40	29	5.5
Average	------	------	------	------	------	[2] 62	6.0
Group IV:							
Clearwater	17	35	25	28	33	28	15.1
Coeur d' Alene	------	33	26	50	40	37	6.9
Kansiksu	18	26	23	38	37	28	15.3
St. Joe	23	24	20	30	34	26	8.8
Average	------	------	------	------	------	[2] 50	11.0
Group V:							
Nezperce	29	61	47	40	41	44	3.6
Selway	30	26	44	47	55	40	7.6
Average	------	------	------	------	------	[2] 57	6.0

[1] Records for period June to September. June and September data are fragmentary.
[2] Group averages are higher than the averages for the forests (as explained in the text), since two or more forests may or may not report storms the same day.

These data show that on areas as large as a national forest, or a group of forests, thunderstorm frequency has been double to quadruple that indicated by W. H. Alexander's isoceraunics (ibid.) in this region. This does not imply any inaccuracy in the Weather Bureau reports,

[2] This is also true of other parts of the western third of the United States.—ED.

but it emphasizes the need for detailed records from the forested mountain areas and for special analyses of such data as a basis for forest-fire weather predictions.

In estimating the danger resulting from lightning storms one might easily be led to believe that the group of forests having the most frequent exposure to lightning as shown in Figure 1 would have the greatest number of fires per unit of area. On such a basis the Kootenai-Cabinet-Flathead-Pend Oreille-Lolo group, with 62 thunderstorm days per year, should show the greatest number of lightning fires per 100,000 acres; but Table 1 shows that this is not the case.

The fact that the number of lightning fires per unit of area is not entirely dependent upon frequency of thunderstorms, is clearly shown by this comparison of data. This lack of correlation can also be shown for the region as a whole when the records for each of the past five seasons are compared. For example, an increase of 12 per cent in the number of storm days from 85 to 95, resulted in an 80 per cent increase in the number of lightning fires, from 1924 to 1925. In 1926 the number of storm days decreased 2 per cent, but the number of fires increased 42 per cent, as compared to 1924. In 1927 there were 2 per cent more storm days, but 28 per cent more lightning fires than in 1924. In 1928 there were 3½ per cent more storm days and 14½ per cent more fires than in 1924. Hence, it appears that regardless of whether the problem is considered by groups of forests, or by years, thunderstorm frequency alone is not a dependable criterion of the probability of lightning-caused forest fires.

This information indicates that forecasts of thunderstorm days are not sufficient as a warning of lightning-fire danger. Additional information is needed for the region as a whole as to the extent and the character of the storms each day. The importance of extent of the storms is demonstrated by Table 2, which shows that as more and more stations within the region report storms in one day, the proportion of reports indicating fire-starting storms increases very rapidly. When there were few storms—only 1 to 10 stations reporting them—usually less than one station per day, or about 5 per cent of the reporting stations, stated that fires resulted. When there were widespread storms—from 201 to 304 station reports in one day— approximately 71 reports, or about 28 per cent, stated that fires resulted.

TABLE 2.—*Comparison of fire-starting storms with thunderstorm days reported, on basis of number of stations reporting storms, 1924–1928*

Stations reporting storms in one day	Thunderstorm days reported, 1924–1928		Reports of fire-starting storms	Reports of fire-starting storms per thunder storm day
Number	*Number*	*Per cent*	*Number*	*Number*
1 to 10	239	54	65	0 27
11 to 20	45	10	63	1.4
21 to 30	29	7	105	3.6
31 to 40	23	5	82	3.6
41 to 50	12	3	69	5.8
51 to 60	10	2	86	8.6
61 to 70	11	3	153	13.9
71 to 80	10	2	128	12.8
81 to 90	9	2	182	20.2
91 to 100	3	1	85	28.3
101 to 120	13	3	230	17.7
121 to 140	7	2	238	24.0
141 to 160	7	2	195	27.9
161 to 200	9	2	345	38.3
201 to 304	11	2	776	70.6
Total	438	100		

It is apparent from this compilation that the fire problem was almost negligible on 54 per cent of the thunderstorm days during the past five fire seasons, when from 1 to 10 stations reported storms each day. However, on 45 days, when from 11 to 20 stations reported storms, there was an average of at least one report that fires resulted. When from 21 to 30 stations detected storms there were nearly 4 reports each day stating that fires resulted. As one report of a fire-starting storm always means that from one to several fires were discovered, it is obvious that the occurrence of fires increases with the number of stations reporting storms, and that the need for forecasts increases in the same way. From the evidence available it appears that whenever less than 40 stations have reported storms in this region in one day no marked regional danger resulted. This might be accepted tentatively as an approximate measure of the need for regional forecasts, the greatest need beginning whenever more than 40 stations are apt to report storms in one day.

Table 3 cites the exact dates, during the 5-year period studied, when more than 40 stations reported the occurrence of lightning storms. This tabulation may be of research value in the study of conditions which have during this period caused greatest forest-fire danger in this region.

TABLE 3.—*Occurrence of dangerous thunderstorm days by number of stations reporting storms*

Number of stations reporting storms	Date of occurrence of storms				
	1924	1925	1926	1927	1928
41 to 60	July 1, 2, 3. Aug. 1.	June 30. July 21, 25. Aug. 13, 18, 26. Sept. 1, 7.	July 7. Aug. 8. Sept. 6.	July 22, 24. Aug. 16, 20, 29.	July 5, 8.
61 to 80	July 4. Aug. 14. Sept. 5.	July 10, 11, 16.	June 29. July 1, 14, 26. Aug. 26.	July 28. Aug. 6, 11, 21.	June 25, 28. July 29. Aug. 2, 14, 26.
81 to 100	July 5. Aug. 13. Sept. 4.	July 12.		July 2. Aug. 23.	June 2. July 12, 26, 27. Aug. 3, 22.
101 to 150		July 17, 23, 29. Aug. 1.	June 30. July 4, 5, 12.	July 14, 25, 26. Aug. 3, 4, 7, 8, 10, 17, 25.	June 26, 27. July 4, 13. Aug. 1.
151 to 200	Aug. 16.	July 22, 28. Aug. 2.	July 6. Aug. 29.	Aug. 1, 2, 22, 28.	July 17, 19. Aug. 25.
201 to 250		July 24.		July 31. Aug. 19.	July 16. Aug. 4, 10, 23.
251 to 304				July 30. Aug. 18.	July 18. Aug. 24.

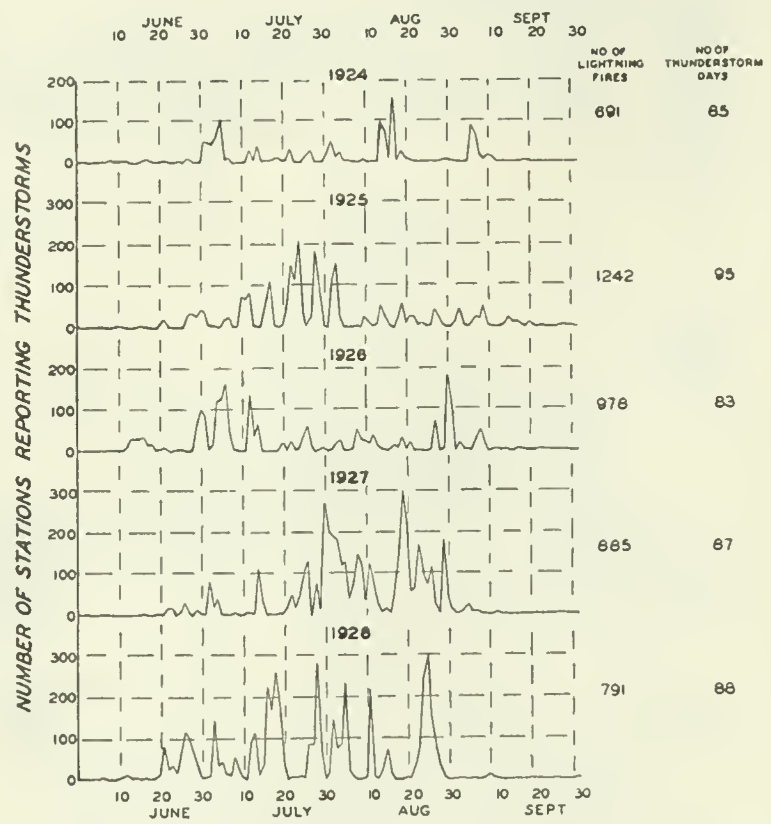
The occurrence and extent of storms are also shown graphically in Figure 2, which reveals, better than a tabular statement, the relation of the days with few reports to the days of widespread occurrence of storms. It is believed that such information should serve as a basis for the study of the weather types that result in storms in the northern Rocky Mountain region, as Alexander (1) has done for the State of Washington. Such work, however, which may prove to be extremely difficult, as pointed out by Henry (8), is more a field for meteorologists. No attempt is made in the present report to analyze this phase of the problem. It is evident, however, that such analysis is basic to most accurate forecasting, and that the collection of field data by the Forest Service should be designed to supply all possible information needed by the Weather Bureau.

CHARACTERISTICS OF STORMS

Although it has been shown that the more widespread the occurrence of thunderstorms the greater the propor-

tion that are reported as starting fires, more information than this must be available to the forest protective organization in order to determine whether exceptional action is needed to meet the danger most efficiently. Some of the factors involved are entirely independent of the thunderstorms, and include the timber type (**13**), the prevalence of inflammable fuels, the seasonal dryness and inflammability of these fuels, and the character of the weather during the preceding days and weeks. These factors are important because green trees, unless covered with lichens, do not ignite as readily as dead trees, or snags. There are more chances of ignition where the volume of dead wood is great than where there is less dead and down wood. Early in the season most of the forest materials are usually considerably wetter, both on the surface and in the interior of the piece, and consequently less inflammable than during late August and early September. Likewise, if recent rains have moistened the forest fuels, or if recent hot spells have dried them, the results of a certain storm or a certain number of storms may differ greatly. All of these factors are recognized by forest protective organizations, and the importance of predictions of lightning storms is rated accordingly.

FIG. II.
OCCURRENCE OF THUNDERSTORMS.



The storms themselves also vary so much that no two may be expected to produce similar results, even though both might theoretically cover equal areas of similar timber type, fuel volume, fuel inflammability, etc. Every experienced forest officer recognizes this fact and knows that there are certain characteristics which distinguish generally safe storms from prolific fire starters. For example, it is obvious that storms with more than the usual number of flashes and with a large percentage of the bolts striking the ground will start more fires than storms with only few flashes, and those largely confined to the clouds. It is also obvious that if the storm brings only a light rain of short duration more fires are apt to result than if the rain is heavy and of long duration. The present study has shown that it is possible to determine average values of these characteristics so that they may be recognized and rated specifically and uniformly by all observers.

Alexander (**1**) has stated, basing his remarks on a few reports for the State of Washington, that the percentage of flashes reported as having been confined to the clouds and the total number of flashes in each storm (the latter not always stated) do not offer a very reliable basis for a comparison of percentages as between "safe" (nonfire-causing) and dangerous (fire-causing) storms and can not at present be given much weight as determinants of the safety factor. He finds a similar lack of authority in reports of the duration of precipitation before and after the flashes. A mathematical analysis of the several thousand reports available for the northern Rocky Mountain region, however, does not support his contention. The analysis shows that the general electrical and rainfall characteristics of lightning storms can be observed by field men and that average conditions can be specified, departures from which will indicate whether the storms being observed are apt to cause more forest fires or are apt to be less troublesome, in this region.

It is highly desirable that these characteristics be determined so that inexperienced lookouts and rangers will be better able to evaluate the degree of danger in the storms that they are observing, often hours before the lightning fires send up enough smoke to be detected. These few hours of possible preparation, between studying the storm and discovering the fires, often determine the difference between full preparation to cope with many fires and lack of that preparation, with resultant large expense and damage. So long as lightning storms do vary in their ability to start fires, and so long as the official forecasts can be expected merely to indicate that storms of some sort will occur, experience has shown that fire control can at present be improved by utilizing even the most generalized estimates of the fire-starting ability of lightning storms.

The present criteria of these conditions are admittedly no better than other mathematical averages based on a large volume of data. They serve, however, to evaluate conditions which are being and must be observed. They provide usable measuring sticks, crude as they may be, for the men who must use them. They represent what is believed to be the first attempt to evolve such criteria of thunderstorm danger, and like most first attempts, they are capable of considerable improvement. A new form of report has recently been devised, which is expected to constitute one small improvement, and the observers are continually being trained to produce more complete and accurate reports. Eventually, it is hoped to improve the data still more by the use of instrumental measurements.

PRECIPITATION

When this investigation was commenced in the northern Rocky Mountain region in 1922, and when the field report form was revised in 1924, an attempt was made to obtain observations of the rainfall with each storm, most of which are single cloud affairs often only a few miles in diameter. Only about half the storm clouds pass directly over observation points, even when these are but 20 miles apart, and consequently rain-gage measurements could not be depended upon to give data on all storms. However,

lookouts at their high mountain-top station are frequently called upon by their supervising ranger to "size up" storms some distance away. Is it raining hard from the storm? How long has it been raining in Deep Creek? What drainages are getting soaked the best? These are typical questions asked of the lookout by his ranger. Therefore, on the new report form lookouts were asked for determinations of the number of minutes of rainfall ahead of the lightning, the intensity of the rainfall accompanying the lightning, and the number of minutes of precipitation after the lightning-bearing section of the storm had passed on, and, when the storm-cloud passes overhead, the actual measurements by rain gage.

Analyses of these data have shown that 92 per cent of the thunderstorms in this region are accompanied by some rain. Hence the information most urgently needed concerns the rainfall ahead of the lightning, which may moisten the fuels so that they will be too wet to ignite; and the rainfall with and following the lightning, which may extinguish any fires that do start. The analyses have failed to find any value in the reports of the intensity of the rainfall accompanying the lightning, and the original reports do not permit a determination of its duration. The other two features have been developed as follows, in Tables 4 and 5.

The outstanding feature of Table 4 is the determination based on 9,549 observations that with the average lightning storm in the northern Rocky Mountain region rain reaches the ground and moistens the fuels at any particular place for about 12 minutes before the lightning commences to flash over or to strike down to that point. This might be called the "scud rain," as it occurs ahead of the lightning-bearing portion of the cloud, approximately under the roll scud, and, as shown by these measurements, passes over very quickly.

Table 4.—*Record of rainfall ahead of the lightning in both wet and dry storms, 1924–1928*

Forest group [1]	Average number of minutes of rainfall by years						Basis, number of observations
	1924	1925	1926	1927	1928	All years	
Group I	7	8	9	4	12	8	662
Group II	6	12	9	16	13	13	864
Group III	12	8	21	11	10	12	4,012
Group IV	19	12	31	9	11	14	2,251
Group V	17	12	20	10	11	13	1,760
Region	13	10	21	11	11	12	9,549

[1] These groups of national forests correspond, with but two exceptions, to those used in the first report on this study, as follows: Group I, Beaverhead, Deerlodge (no data), Helena; Group II, Lewis and Clark, Missoula, Bitterroot; Group III, Blackfeet, Flathead, Cabinet, Kootenai, Lolo, Pend Oreille; Group IV, Clearwater, St. Joe, Coeur d'Alene, Kaniksu; Group V, Selway, Nezperce. The exceptions are the stopping of records from the Jefferson Forest, which was included in Group I of the first report, and the change of the Lewis and Clark from Group I to Group II, where its fire records assign it with most agreement.

Table 5.—*Record of rainfall following the lightning in both wet and dry storms, 1924–1928*

Forest group	Average number of minutes of rainfall by years						Basis, number of observations
	1924	1925	1926	1927	1928	All years	
Group I	42	25	42	33	44	29	651
Group II	15	34	28	38	30	31	855
Group III	46	29	70	34	33	39	4,010
Group IV	56	26	81	33	27	38	2,187
Group V	28	40	55	37	32	38	1,781
Region	40	31	64	35	33	37	9,484

The most important fact in Table 5 is the regional average for the 5-year period, showing that on the basis of 9,484 observations there is an average of 37 minutes of rainfall which may be counted on after the lightning has ceased to moisten the fuels and prevent the spread of fires caused by the lightning. This rainfall following the lightning probably is largely the so-called "secondary rain" described by Humphreys (**9**) in his analysis of the structure and behavior of thunderstorms.

In the preliminary investigation, based on the data for 1924 and 1925, averages of 11 minutes' rainfall ahead of the lightning and 33 minutes' following it were obtained. These averages were based on 2,455 reports. It is obvious from Tables 4 and 5 that the addition of data for three more seasons, raising the basis to over 9,400 reports, has not changed the first determinations materially.

Knowing the average duration of rainfall ahead of the lightning, and following it, the important question immediately arises: Do the storms that started fires show any appreciable differences in amount of rainfall when compared to storms that did not result in fires? The available data on this phase of the problem are shown in Tables 6 and 7. The number of reports used as a basis in these tables is less than shown in Tables 4 and 5, because many reports failed to state specifically whether or not the storm started fires.

Table 6.—*Record of number of minutes of rainfall ahead of the lightning in fire-starting as contrasted with nonfire-starting storms, 1924–1928*

Year	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Basis, reports	Average rainfall	Basis, reports
	Minutes	*Number*	*Minutes*	*Number*
1924	16	391	9	253
1925	9	718	8	426
1926	29	670	13	334
1927	12	1,622	7	575
1928	11	734	8	532
Total and average	14.6	4,135	8.7	2,120

This table shows an average difference of 5.9 minutes in the duration of the scud rain ahead of the lightning is dangerous as compared to safe storms. Although this is a small absolute quantity, it is proportionately very large (68 per cent of the 8.7-minute average); and it is also consistently true that each year the nonfire-starting storms have a greater average rain than the fire-starting storms. This being true, and considering the basis of 6,253 reports over a 5-year period, it seems entirely safe to conclude that there is an appreciable and a significant difference in the amount of the rainfall ahead of the lightning in safe and dangerous storms.

Table 7.—*Record of number of minutes rainfall following the lightning in fire-starting as contrasted with nonfire-starting storms, 1924–1928*

Year	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Basis, reports	Average rainfall	Basis, reports
	Minutes	*Number*	*Minutes*	*Number*
1924	50	414	34	257
1925	32	736	27	436
1926	74	695	44	338
1927	38	1,581	32	578
1928	37	730	23	529
Total and average	44.0	4,156	30.8	2,138

In Tables 7, again, for the secondary rain following the lightning, the data show 13.2 minutes, or 43 per cent longer rainfall for storms which did not start fires than for dangerous storms. Here, also, a large number of reports covering a 5-year period are used as a basis. And again the data are consistent; no average for any one year in the fire-starting storms is greater than the general average for all nonfire-starting storms, and no single average for the safe storms is less than the general average for the dangerous storms.

Tables 6 and 7 seem to demonstrate rather conclusively that fire-starting storms in this region are generally characterized by less rainfall, both ahead of and following the lightning, than safe storms which are characterized by precipitation over longer periods.

The principal purpose served by these averages in Tables 4, 5, 6, and 7 is the approximate determination of a condition which varies within wide limits, so that definite averages can be stated above which departures generally indicate less than the usual need for fire control, and below which departures indicate more need for action. The averages given, however, include both dry and wet storms. It is therefore possible to eliminate the dry storms and by considering only those which brought some rainfall, either ahead of or following the lightning, to determine the duration of the rainfall only for the wet storms. Naturally, this duration will be appreciably greater than the average determined on the basis of both wet and dry storms.

Of 7,093 reports of both classes of storms only 48 per cent state no rain ahead of the lightning. The remaining 52 per cent state an average of 25 minutes of rain ahead of the lightning. As would be expected, this is approximately double the average for both wet and dry storms. On this basis it is evident that the average storm reported as having rain ahead of the lightning may be expected to bring about 25 minutes of precipitation.

The records show that there is a smaller proportion of storms that are dry following the lightning than of those that are dry ahead of the lightning. Only 33 per cent of a total of 6,983 reports stated that no rain fell after the lightning had passed on. The other 67 per cent show an average rainfall of 58 minutes' duration. This time interval, which can be used as an additional criterion of degree of danger in this region, indicates that the "secondary rain" described by Humphreys occurs in about two-thirds of all the thunderstorms in this region, and lasts for about one hour.

Further examination of the data on rainfall ahead of the lightning, by subdivisions of the region, shows that, for each of the five groups of forests previously described, the conclusion holds true that there is less rainfall ahead of the lightning with fire-starting storms than with safe storms. Table 8 shows the averages and the number of reports on which they are based, for each of these groups.

TABLE 8.—*Record of number of minutes' rainfall ahead of lightning in fire-starting as compared with nonfire-starting storms, by forest groups, 1924–1928*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Reports	Average rainfall	Reports
	Minutes	*Number*	*Minutes*	*Number*
Group I	8.8	511	2.8	33
Group II	12.8	545	6.7	97
Group III	15.4	1,637	6.8	803
Group IV	18.4	749	9.6	687
Group V	14.5	693	11.3	500
Region	14.6	[1] 4,135	8.7	[1] 2,120

[1] Reports used for Table 8 are the same as used for Table 6.

In the same way the data on rainfall following the lightning (Table 9) show that in each of the five groups of forests there was less rain after the lightning in fire-starting storms than in safe storms.

TABLE 9.—*Record of number of minutes rainfall following the lightning in fire-starting as compared with nonfire-starting storms by forest groups, 1924–1928*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Reports	Average rainfall	Reports
	Minutes	*Number*	*Minutes*	*Number*
Group I	36.0	507	23.2	36
Group II	34.2	548	18.4	99
Group III	47.0	1,662	31.8	802
Group IV	51.0	753	28.4	687
Group V	42.9	686	35.2	514
Region	44.0	[1] 4,156	30.8	[1] 2,138

[1] The reports used for Table 9 are the same as used for Table 7.

No attempt is made in this report to determine statistically the probable error of these averages, or the significance of differences between the averages for the various groups. Apparently the actual use of the criteria by lookouts and others will not be affected at present if the regional averages are used by all forests regardless of their group, because in all cases departures from the regional averages are similarly significant in each of the groups.

DRY STORMS

Although most lightning storms bring some rain with them, so-called "dry lightning storms" are often credited with starting a large proportion of forest fires in this region. It is entirely reasonable to believe that such storms are decidedly apt to start fires if their bolts are numerous, and if they reach dry fuels on the ground. The records show, however, that only 6 to 10 of every 100 lightning storms recorded in this investigation (14,754 reports) were dry, delivering no rain whatever to the ground beneath the storm cloud. The reports (8,408) which were definite with regard to both the rainfall and the fire-starting character of the storms, showed that only 33 per cent of the dry storms were fire starters. Hence, only 2 or 3 storms out of 100 are both dry and fire starters.

The occurrence of these dry lightning storms in this region is interesting in two respects. First, these reports prove the occurrence of a type of thunderstorm not included by some meteorological definitions; and, second, the so-called dry storm is popularly credited in this region as being the most dangerous fire starter. During the 5-year period covered by this study, the tabulation of 1,238 reports of lightning storms with no rain before, with, or following the lightinng, out of a total of 14,754 reports, should remove all doubt as to dry storm occurrences. And such conditions depart decidedly from Clayton's descriptions (4) and disagree with Moore's definition of a thunderstorm (**10**). This definition reads: "The thunderstorm, so familiar to everyone, may be defined as a local rain accompanied by lightning, thunder, gusts of wind, and frequently hail." Humphrey's definition (Op. cit.), "A thunderstorm, as its name implies, is a storm characterized by thunder and lightning . . .," appears to apply more conclusively in this region.

Of the reports of absolutely dry storms, stating definitely whether or not fires resulted, 68 per cent showed that no fires resulted. Of the definite reports of wet storms,

on the other hand, 66 per cent stated that no fires resulted. This close similarity refutes the popular conception that dry storms as a class are more dangerous than wet storms. It also raises a question concerning other data, previously presented, which show for the majority of lightning storms that with less rain there are more fires, and with more rain less fires.

The reason for this apparent anomaly undoubtedly lies in the nature of dry thunderstorms, in which the flashes are generally few, and nearly all confined to the clouds. The meteorological reasons for these peculiarities in activity may lie in the well-supported theories (9) that violent, turbulent action of large masses of drops of water forming the cloud are most favorable to the generation of lightning, and that practically continuous sheets of water (rain drops) and streaks of highly ionized air form favorable paths for the bolts. Hence, clouds too small to precipitate moisture enough to reach the earth (as in dry storms) may often be large enough and active enough to generate a few flashes which will be almost entirely confined to the clouds. Large, active, and rain-producing clouds, on the other hand, may be expected to produce a greater number of flashes, with a greater number of bolts striking the ground.

LIGHTNING

That the proportion of the lightning flashes confined to the clouds has an appreciable effect upon the starting of fires is shown by the analysis of the records bearing on this feature. Table 10 shows this for the region as a whole by years. The safe storms consistently show a higher percentage of lightning confined to the clouds than do the dangerous storms.

The significance of data concerning percentage of lightning confined to the clouds, and striking the ground, obviously would be increased if the total number of flashes per unit of time, or the total number as a storm passed over a certain spot, were known. It has been found difficult, however, to obtain such counts as accurately as desired. Consequently, this aspect of the problem can not be examined at present. Work is being done, nevertheless, to obtain this information for later use.

Table 10.—*Percentage of lightning flashes confined to the clouds*

Year	Nonfire-starting storms		Fire-starting storms	
	Flashes, confined to the clouds	Basis, number of reports	Flashes, confined to the clouds	Basis, number of reports
	Average per cent		*Average per cent*	
1924	73	468	61	318
1925	68	835	55	565
1926	71	854	55	442
1927	80	2,470	58	736
1928	76	860	53	670
Average and total	76	5,487	56	2,731

This summary for the region, based on 8,218 observations, shows 20 per cent more lightning confined to the clouds in safe storms than in dangerous ones. From these data it is possible to establish indexes of the degree of danger as influenced by this factor. It is apparent that as a general rule if less than half of the lightning is confined to the clouds the storm is of the fire-starting type, whereas if more than three-fourths of the lightning stays in the clouds the storm is of the safe type. Intermediate amounts probably should be considered as more dangerous than safe.

A sorting of these data by groups of forests, rather than by years, also shows uniformly that the safe storms have more of their lightning confined to the clouds than do the dangerous storms. Whereas the first report on this investigation, which covered only the data for 1924 and 1925, indicated that there might be a slightly significant difference between groups of forests in the percentage of lightning confined to the clouds, the present and more comprehensive data show rather uniform percentages. As is evident from Table 11, no group average varies more than 9 per cent from the average of any other group, and none departs more than 6 per cent from the regional averages. Apparently, the criteria of degree of danger according to the amount of lightning confined to the clouds, as established on the basis of the regional data, are applicable in each of the subdivisions.

Table 11.—*Percentage of lightning flashes confined to the clouds in safe and dangerous storms*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Flashes, confined to the clouds	Basis, number of reports	Flashes, confined to the clouds	Basis, number of reports
	Average per cent		*Average per cent*	
Group I	72	568	50	38
Group II	76	726	55	133
Group III	77	2,235	58	1,016
Group IV	78	975	53	865
Group V	72	983	59	679
Average and total	76	5,487	56	2,731

OTHER CHARACTERISTICS

In addition to the rainfall, or lack of it, and in addition to the character of the lightning, there are other features of lightning storms which affect successful forest-fire control. These include the time of day when the storms are first seen, the prevalence of storms after dark, the passage directly over the lookout stations, and the common direction of storm movement.

When lightning storms are recognized as such during the forenoon hours, it is generally possible for a ranger or his assistant to get in touch by telephone with his various employees, including trail crews, before the resultant fires have begun to be discovered by the lookouts. This is, therefore, one possibility of obtaining greater speed in fire control.

Table 12 shows the percentage of reports by years and by groups of forests, stating that the storms were first seen during the forenoon hours.

Table 12.—*Storms first seen in the morning, by forest groups*

Year	Group I	Group II	Group III	Group IV	Group V	Regional average
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1924	24	13	18	19	35	23
1925	17	13	25	27	25	24
1926	25	31	31	32	44	34
1927	16	17	20	23	27	22
1928	22	20	23	28	30	25
Average	20	20	24	26	31	25

The outstanding indication from this compilation, based on over 14,000 observations, is that about one storm out of four is first seen before noon, and thereby permits fire-control action early in the day if the lookout immediately reports storms to his ranger.

The consistently high percentages shown by Table 12 for all groups of forests during 1926 may be of meteorological significance, and it is hoped that the study of such phases will appeal to some meteorologists. It should be mentioned here that all of the reports, for the entire day, have been specially sorted and tabulated on an hourly basis at the request of the Spokane office of the United States Weather Bureau, so that the development of storms throughout this region may be studied intensively in relation to the twice daily synoptic weather maps. From this study it is hoped to derive considerable information of value for increasing the accuracy of future forecasts and for localizing them.

The prevalence of storms at midnight has been determined merely as an approximation of the number of storms occurring during the middle of the night. The data show the following percentages of the total number of observations, which stated that the lightning storms were occurring at that hour: 1924, 5 per cent; 1925, 3.5 per cent; 1926, 7 per cent; 1927, 4 per cent; and 1928, 4.5 per cent; average for the 5-year period, 4 per cent. The importance of storms occurring during the hours of darkness lies in the inability of the lookouts to detect the resultant fires, unless the flames are so located as to be directly visible. In the meantime, and before men can reach the spot and commence suppression, the fire may have several hours in which to spread. Furthermore, since it is very difficult at night for the lookouts to make azimuth readings of lightning bolts striking, the effects of storms at night can not be accounted for so accurately. With some 4 per cent of the storms occurring at midnight, it is obvious that an appreciable number of storms are in action during the night when close observation is extremely difficult or impossible. Compilations of future data will be made to develop more specific information on this phase of the problem.

The passage of lightning storms directly over a lookout station is important in several ways. Frequently the resultant fires will be close to the station and can be attacked immediately. On the other hand it often happens that a storm cloud whose path includes the mountain top lookout station will envelop the station and reduce visibility from that point to such a degree that the direction of lightning flashes can not be discerned and resultant fires only a half mile away are invisible until the cloud has moved by.

The reports by the lookouts show the following percentages of cases in which the storms passed directly over one or more of the lookout stations: 1924, 48 per cent; 1925, 47 per cent; 1926, 47 per cent; 1927, 42 per cent; 1928, 39 per cent. This means that in about 4 or 5 of 10 observations a storm will pass directly over some lookout station and consequently that many reports on storms will be, and frequently must be, made by stations at some distance from the storm. Hence, no method of observation should be used which depends upon the storm passing directly over the observation station.

Probably the best method of determining whether or not storms are apt to start fires near lookout stations, and the likelihood of such clouds reducing visibility from that point, will be to examine the data separately for each lookout. It is believed, however, that there is not yet a sufficient volume of reports for individual stations to warrant such a detailed sorting and tabulation. Such an analysis is planned for some future date.

One feature of storm occurrence upon which we have no dependable data is the altitudinal range of the clouds, which might influence or even control zones of lightning danger as Ward (14) has described them on the authority of F. G. Plummer (12). These zones are specifically defined as being areas of lightning danger, but it is implied that high mountain tops may be above the clouds and so in a zone of safety. To investigate the occurrence of lightning-fire zones the locations of several thousand lightning fires in the northern Rocky Mountain region have been plotted on maps by H. R. Flint, in charge of fire control of the Forest Service in this region. Although these maps show conditions for more than 10 years, there is not any consistent evidence that lightning fires occur in zones limited altitudinally in any way, except by the absence of inflammable material, and by the wetness of these fuels. There is, instead, a most baffling scattering of these fires which renders the problem of successful control all the more difficult. It is recognized that these maps show merely the occurrence of lightning-caused fires and, therefore, not all points struck by lightning, but this appears to be the best information available.

Flint is also making a study of the occurrence of lightning fires in relation to mineral-bearing areas in an effort to determine whether or not geological formations have any appreciable effect upon lightning strokes and fires. The Forest Service fire records and the geologic maps for the Coeur d'Alene region are being used for this work.

Another characteristic of lightning storms that may have meteorological significance which will be of value in prediction is the common direction of storm movement in different parts of the northern Rocky Mountain region. There are 14,595 reports which serve for determining this characteristic of storms for this region. Tables 13 and 14 show the results of the analysis by years and by groups of forests.

TABLE 13.—*Direction of movement of storms, by years, toward the directions given*

Movement of storm	1924 reports		1925 reports		1926 reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	196	16	333	13	267	12
Northeast	456	36	891	36	671	31
East	371	29	762	31	651	30
Southeast	80	6	215	9	199	9
South	36	3	70	3	89	4
Southwest	36	3	64	3	91	4
West	31	3	52	2	73	4
Northwest	40	3	87	3	89	4
Stationary or revolving	18	1	7	0	34	2
Total	1,264	100	2,481	100	2,164	100

Movement of storm	1927 reports		1928 reports		Total reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	461	11	451	10	1,708	12
Northeast	1,207	28	1,233	28	4,458	31
East	1,383	32	1,403	32	4,570	31
Southeast	425	12	714	16	1,731	12
South	248	6	259	6	702	5
Southwest	140	3	134	3	465	3
West	107	3	79	2	342	2
Northwest	158	4	100	2	474	3
Stationary or revolving	47	1	39	1	145	1
Total	4,274	100	4,412	100	14,595	100

Table 13 clearly shows the marked tendency of lightning storms to travel toward the northeast and east in this region. Only 12 per cent of the reports show a movement toward the north, and the same proportion toward the southeast, all other directions being credited with only 5 per cent or less. The changes from year to year during the period studied do not appear to be significant.

Table 14 indicates that there are no marked differences in direction of storm movement between the various groups of forests. While Group I, in the northeastern part of the region and largely east of the Continental Di-

vide, shows the highest percentage of movement toward the east, Group V, in the southwestern part of the region, shows the greatest movement toward the north and northeast. The significance, if any, of these differences is a problem for the meteorologists. Perhaps these data serve as an index of the probability of summer rain, from each cardinal direction, but the practical application of such information in fire control is doubtful.

TABLE 14.—*Direction of movement of storms, by forest groups (movement toward the directions given)*

Movement of storm	Group I reports		Group II reports		Group III reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	55	7	146	11	694	11
Northeast	281	34	396	31	1,514	25
East	339	42	503	39	1,918	31
Southeast	57	7	115	9	975	16
South	22	3	41	3	391	6
Southwest	17	2	26	2	231	4
West	14	2	37	3	148	2
Northwest	24	3	33	2	217	4
Stationary or revolving	2	0	2	0	57	1
Total	811	100	1,299	100	6,145	100

Movement of storm	Group IV reports		Group V reports		Region reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	424	12	389	13	1,708	12
Northeast	1,003	29	1,264	43	4,458	31
East	1,006	29	804	28	4,570	31
Southeast	388	11	196	7	1,731	12
South	198	6	50	2	702	5
Southwest	137	4	54	2	465	3
West	102	3	41	1	342	2
Northwest	121	4	79	3	474	3
Stationary or revolving	57	2	27	1	145	1
Total	3,436	100	2,904	100	14,595	100

One other feature of the movement of lightning storms has a possible bearing on fire control. This concerns the possible tendency of storms to follow more or less regular paths, perhaps according to the topography or the local presence or absence of thunderstorm-breeding conditions, as Brooks (3) and Hallenbeck (7) have described them.

Naturally, the determination of localities most frequently exposed to lightning storms is of great importance in deciding upon the forest protection facilities that should be provided for different areas. Field observers in this region are strongly of the opinion that certain topographic features and localities are common centers of formation of storms and that there are certain paths of movement which are followed much more frequently than other paths. The present records covering all subdivisions of the region have not been exhaustively examined, but detailed analyses have been made of several restricted areas, comprising up to about a million acres, and for some of the most dangerous days thunderstorm reports for the entire region have been plotted on maps. These minor studies have failed to find any marked topographic paths along which thunderstorms may commonly be expected to travel. It is planned to investigate these conditions more intensively a few years hence, after the volume of records from each station has increased materially.

LIGHTNING-CAUSED FIRES

The number of lightning fires per unit of area is a basic consideration for forest-protective agencies. This figure is not the same for different parts of the United States, nor even for different parts of the northern Rocky Mountain region, being governed largely, as has been seen, by the number and characteristics of storms.

When storms are accompanied by more rain than the average and when they have more than the usual amount of lightning confined to the clouds, a smaller proportion of them cause fires. When they are accompanied by less rain than the average, however, and have most of the lightning striking the earth a larger proportion is dangerous. Though the seasonal wetness or dryness of the forest fuels undoubtedly influences the probability that a storm of certain character may start fires, the two conditions, occurrence of storms (as indicated by number of thunderstorm days) and the characteristics of storms (as shown by percentage of storms starting fires) are essentially indicative of the lightning fire hazard per unit of area in a given timber type in this region.

The relationship between storm occurrence, characteristics, and the number of resultant fires can be expressed as a simple formula which, when applied to the data for each of the five regional subdivisions, serves to compute the average number of lightning fires per unit of area with a maximum error of one and one-half fires per 100,000 acres. The formula used was $\frac{10b}{a}=c$. The data are shown in Table 15.

TABLE 15.—*Thunderstorm occurrence, danger and fires*

Forest	Average thunderstorm days per year (a)	Reports showing storms starting fire (b)	Actual lightning fires per 100,000 acres per year	Computed lightning fires per 100,000 acres per year (c)
	Number	*Per cent*	*Number*	*Number*
Group I	56	6	1	1
Group II	43	15	2	3½
Group III	62	31	6	5
Group IV	50	47	11	9½
Group V	57	41	6	7
Region	87	34	5	4

The data in Table 15 show again that occurrence of storms is not, by itself, a satisfactory index of the degree of danger of lightning fires. Before the degree of lightning-fire danger can be estimated satisfactorily fire weather forecasts must consider other factors—the characteristics of the storms and probably the seasonal and current moisture content and inflammability of the forest materials. As has been shown, these conditions can be observed and measured with sufficient accuracy to improve very greatly the knowledge of probable danger. The combination of conditions resulting in the highest degree of local danger consists of numerous storms of the fire-starting type covering a small and often inaccessible area on which the fuels are extremely dry.

Table 15 also shows the relative danger of lightning storms for the region and for each of its subdivisions. For the region as a whole about 34 storms out of 100 are dangerous, while for the subdivisions this figure varies from 6 to 47. The actual average number of fires per unit of area show that the importance of the lightning problem varies more nearly with the percentages of storms starting fires (i. e., storm characteristics) than with mere storm occurrence.

There is one other feature of lightning fires which is of great importance in successful fire control. This is the period of time which commonly elapses between the first sighting of a storm by a lookout and the discovery from the same station of each of the resultant fires. It is obvious that if a storm is sighted some hours before the fires it started are discovered, such a period offers greater

opportunity for the lookout to inform his ranger of the path of the storm, the probability of fires, and even the probable location of fires, according to his observations of where lightning is striking. Likewise, a long period offers the ranger more time to request an air patrol of his district, and more time to communicate with his fire guards, smoke chasers, patrolmen, and road, trail, and telephone construction or maintenance crews, so that they may move to more strategic locations if the ranger desires. All this will assist greatly in catching fires while small—the first essential in effective fire control. Prompt and well-advised action is therefore required, especially when not enough men are regularly employed to attack an exceptional number of fires efficiently. Speed and dependable information are even more important in the region under study than elsewhere, because here are several national forests with an average of only 16 to 18 miles of road and trail per township of 23,040 acres, and measured travel off the trail is at the seemingly low average rate of only 1 mile per hour. Under such conditions it is extremely desirable to grasp all opportunities for moving men as early as possible to locations from which a minimum of travel will be required to reach the fires.

As an index of the time available for reporting on the important features of lightning storms before the fires are detected, 4,149 reports state definitely the time when the storm was first seen and the hour and minute when the fires were discovered. Of these 2,338 reports show the time between first sighting the storm and the discovery of the first fire, 959 reports state the time before discovering the second fire, 538 reports cover a third fire, and 314 give data for a fourth. The results have been arranged to represent conditions for an average lookout station and show the probability of a first discovery of a fire within definite periods of time after sighting the storm, or if two fires are discovered the probable elapsed time for the second discovery and similarly for third and fourth fires. The records show that occasionally a single lookout has reported 10 or 12 fires caused by one lightning storm, but the majority of the reports show far less than this.

When the cumulative percentage of discoveries were plotted by hourly periods (hours following the first sighting of the storm) and the data were curved, the values given in Table 16 were obtained.

TABLE 16.—*Percentages of storm reports showing various intervals between sighting of storm and discovery of subsequent fires*

Hours after first sighting storm	First fire	Second fire	Third fire	Fourth fire
	Per cent	*Per cent*	*Per cent*	*Per cent*
0 to 1	20	16	12	8
1 to 2	16	12	12	13
2 to 3	11	11	10	8
3 to 4	8	9	9	6
4 to 5	5	6	5	4
5 to 6	4	4	5	4
6 to 12	12	14	15	16
12 to 18	7	8	8	11
18 to 24	5	6	6	7
24 to 48	5	6	8	9
Over 48	7	8	10	14
Total	100	100	100	100

Table 16 shows that the period of time between first sighting the storm and the discovery of fire lengthens very appreciably with each subsequent fire. For example, about half the first fires are discovered within three hours after the lookout first sees the storm. In other words, to be amply prepared to reach and hold as many as half of the first fires, only three hours is available for presuppression action after the storms are sighted. Four hours can be allowed for equal preparation for second fires, five hours for third fires, and over six hours are available for the majority of the fourth fires. The importance of these determinations lies in the fact that regardless of whether or not lightning storms have been previously predicted by the Weather Bureau, there is, after the storm actually appears, a very appreciable period of time available to mobilize men and otherwise prepare for the probable fires. Obviously, in regions like northern Idaho, where 4 or 5 storms out of 10 usually start fires, such an opportunity for preparation is decidedly desirable.

Another important fact indicated in Table 16 is the considerable number of discoveries of fire made only after a lapse of 48 hours. For the region as a whole, for the 5-year period, 333 reports show this so-called "hang-over" condition. These reports comprise 8 per cent of the reports studied, and it is worth mentioning here that in 160 instances in these reports these hang-overs were first discoveries. Consequently, it is obvious that even though a lightning storm passes by and no fires are discovered within the following two days, there is still an appreciable chance that fires, were started and will show up later on.

TABLE 17.—*Percentage of fires discovered 48 hours or more after the storm was first seen*

Year	First fire	Second fire	Third fire	Fourth fire
	Per cent	*Per cent*	*Per cent*	*Per cent*
1924	8	3	1	4
1925	10	15	20.5	23
1926	6.5	12	15	20
1927	6	5	8	15
1928	5	4	4	6
Average	7	8	10	14

Table 17 shows that since 1925 there has been a consistent reduction in the percentage of discoveries made more than 48 hours after the storm appeared. Whether this has been brought about by the establishment of more lookout stations directly surveying more area, the removal of old stations to new and better locations, or by better trained and more conscientious personnel can not be determined from these reports. A marked and very desirable improvement in fire control is evident, nevertheless.

When the speed of detection is compared for the five subdivisions of this region the most outstanding fact is that the Beaverhead-Helena group of forests, which has very few lookout stations at high elevations, shows a consistently longer period of time between sighting the storm and making the first discovery of a fire. For example, four hours after the storm appears only 50 per cent of the first discoveries have been made on the Beaverhead-Helena group, while 60 per cent have been made on the north Idaho forests comprising Group IV. Twelve hours after the storm is first seen the eastern Montana forests have made only 66 per cent of their first discoveries, while Group IV has made 77 per cent and Group V 79 per cent. At the 24-hour mark the Beaverhead-Helena have only 74 per cent to their credit, while Groups IV and V have 89 per cent and 90 per cent, respectively.

In this region there are two other observations which have also been found of immediate value and usefulness. The first is the measurement of azimuths or compass bearings on points struck by lightning and the recording of these measurements so that these spots can be watched very carefully for at least 48 hours to come. (A special

form is provided for noting such observations.) As a result of such action many fires may be discovered as soon as the first wisp of smoke rises from the spot and hours before the usual smoke column begins to be clearly visible. The second observation is whether the spots struck by lightning are well soaked, lightly sprinkled, or entirely unmoistened by the storm. Experience has shown that even with storms bringing heavy rainfall lightning may strike one or more places near the edge or even outside the area wetted. Naturally, if the fuel types are similar, a bolt falling outside the rain area will have a better chance of starting a fire than one at a spot which is thoroughly soaked by rainfall. But of even more importance is the fact that if fires result in both cases the one outside the rain area is much more in need of immediate attention than the one that is surrounded by wetter fuels, and the former should be attacked first if there must be a choice. Usually the lookout is the only member of the forest protective organization who is in a position to make this important fact known to the ranger, central dispatcher, or whomsoever may be responsible for sending men to these fires.

SUMMARY

Because lightning is the most important single cause of forest fires in the northern Rocky Mountain region a special study has been made by the Forest Service of the occurrence and characteristics of lightning storms in that region. This study utilized the data obtained from fire lookouts stationed on approximately 200 mountain tops, so distributed that very few storms could occur during the summer months without being reported by the lookouts. A special form was used for obtaining the desired information, which is now summarized for the 5-year period 1924 to 1928, inclusive.

The results show that about 34 storms out of 100 have caused forest fires and that there are from two to four times more thunderstorm days per year in this region than had been previously estimated. It is found, however, that the danger of forest fires caused by lightning is not in proportion to the number of thunderstorm days but varies more with the characteristics of the storms. The greatest number of fires and the greatest proportion of reports of fire-starting storms were found on 20 days, which constitute only 4 per cent of the total number of thunderstorm days. Records are included so that these so-called easy and bad days may be studied in relation to the daily weather maps.

An analysis of the 14,754 lookout storm reports available shows that there are recognizable differences between the types of storm that usually start fires and the types that are generally safe. These differences are found to lie in the duration of the rainfall ahead of and following the lightning, together with the electrical activity of the storm and the percentage of lightning flashes confined to the clouds or striking to the earth. Average duration of rainfall, and average percentage of lightning flashes striking to the ground, have been determined separately for the safe and for the dangerous storms. It is pointed out that by observing these characteristics it is often possible for the lookouts to classify a storm as either generally safe or generally dangerous hours before any of the resultant fires produce enough smoke to permit discovery. Such advance information permits the forest protective agency to move men into or near the danger area so that the fires can be reached more quickly and be extinguished more cheaply while yet small.

It is found that the so-called dry storm (having no rainfall reaching the ground) occurs in only 6 to 10 cases out of 100. Of all these dry storms only one-third started fires, whereas one-third of the wet storms were also dangerous. The reasons for this anomaly are believed to be in the lesser number of lightning flashes in dry storms together with a lesser proportion of these flashes reaching the ground. Naturally, no fires can be started by a dry storm if all of the lightning is confined to the clouds.

* * * * *

From these facts, developed by the analysis of the reports on lightning storms, it is obvious that there are four observations which forest-fire lookouts can make which are of immediate value to the forest ranger directly in charge of fire control: (1) The occurrence of storms; (2) their paths: (3) the accompanying precipitation, if any; and (4) the percentages of lightning confined to the clouds and striking the ground. Always, the flash of lightning or the rumble of thunder will be the best assurance of thunderstorm occurrence, but usually the formation of cumulus clouds of the thunderstorm type and size is sufficiently definite, especially if storms have been predicted by the Weather Bureau. As the storm develops and the lookout is able to estimate its probable path he may be able to determine whether the particular ranger district which includes the lookout station is apt to be affected. If it is, then some prominent topographic feature will serve to time the duration of rainfall and to estimate the character of the lightning as the storm passes over that point. Such information, obtained by a careful observer, is now recognized as an excellent basis for fire control action in the northern Rocky Mountain region.

Some other characteristics of storms determined by this study include the finding that 25 per cent of the storms are first seen before noon; about 4 per cent of the storms are active during the middle of the night; only 4 or 5 observations out of 10 report the storm as passing directly over the observation station, thereby indicating the local character of lightning storms in this region; 62 per cent of all thunderstorms in the northern Rocky Mountain region move toward the northeast and east, while 86 per cent are found to travel in a direction between north and southeast; no common topographic paths of travel have as yet been discernible.

This study is to be continued, using an improved report form to obtain additional detail of information as well as to record if possible any increase or decrease in the occurrence of lightning storms over a longer period.

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THE CALENDAR YEAR AS A TIME UNIT IN DROUGHT STATISTICS[1]

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[Weather Bureau, Washington, March 17, 1931]

As almost everyone knows, the year is generally considered as being too long a unit for use in compiling drought statistics. While admitting the general soundness of that view, it is believed that the disadvantages of the calendar year have been somewhat exaggerated. The case of Arkansas in 1930, when the percentage of the normal precipitation received was 96 per cent, will naturally come to mind. In this case two of the months, January and May, had 223 and 200 per cent of the normal, respectively, and the real lack of rain that caused the failure of the cotton crop was confined to the months of June and July, with 22 and 19 per cent, respectively. Most persons fail to consider that the very great rainfall of January and May was in itself quite abnormal and not likely to again happen in the next 50 years.

The reason why a shorter period than the year has not heretofore been used in compiling drought statistics is most likely because of the overlapping of drought periods from one month to the next and the fact that its ending rarely occurs at the end of a month; thus it would be necessary to make a special compilation in order to fix the definite limits of the duration of droughts. This has not been done, and to do it now for previous droughts is prohibitive on account of the labor involved.

The object of the present compilation was therefore to ascertain to what extent the calendar-year record of precipitation would serve to accurately fix the times and places of drought in the United States. In the beginning of the study the individual records of stations within a State using both the monthly and annual amounts were used. As the work progressed the difficulties of distinguishing the beginning and the ending of drought even from the monthly totals of precipitation led to its abandonment and the substitution of a shorter method based on the averages of precipitation for each year for each of the 42 districts organized into what were formerly known as State weather services, now known as climatological sections, of which as a rule there is one in operation for each State or combination of States, except that the six New England States are organized under the name "New England," and Delaware and the District of Columbia are combined with Maryland. The list of sections with the term of years covered by each section is given in Tables 1 and 2.

In some of the sections the record goes back to the early eighties and in others it does not begin until about 1900, so that the early part of the period is not as fully covered as that part subsequent to 1900. The size of the respective sections varies greatly—say, from about 15,000 square miles in the smallest to 265,896 in the largest. The network of climatological stations is somewhat closer east of the Mississippi than to the westward, especially in Rocky Mountain and Plateau States.

The plan followed was to take out for each State the least annual precipitation that had been recorded during the forty-odd years during the life of the record, then the next lowest annual amount, and so on, on an ascending scale until the tenth year on that scale had been reached. Thus it has been practicable to construct for each State a diagram beginning at the low point and increasing to, say, about 90 per cent of the annual average precipitation. In like manner the year of greatest annual precipitation has been taken out and the nine subsequent years when the next greatest annual amount was received, and so on until the tenth year, on a decreasing scale, had been reached.

Tables 1 and 2 include the tabulation above described, the annual amounts of precipitation being expressed as a percentage of the mean annual or, in other words, the normal for the State.

In Table 1 the scale is an increasing one and in Table 2 a decreasing one.

[1] The substance of this article was presented before the May, 1931, meeting of the American Meteorological Society in Washington, D. C.

TABLE 1.—*Years of deficient precipitation in the United States—Percentage of actual precipitation expressed in percentages of the normal*

States	State means (inches)	Period covered	1		2		3		4		5		6		7		8		9		10	
			Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent
Alabama	52.4	1884–1930	1904	75	1889	83	1914	86	1921	87	1896	87	1910	87	1930	88	1924	91	1897	91	1894	91
Arizona	13.8	1897–1930	1900	60	1889	61	1924	64	1910	66	1928	72	1904	72	1903	72	1902	76	1901	77	1929	82
Arkansas	47.7	1891–1930	1901	75	1924	78	1896	80	1917	85	1899	88	1925	89	1916	89	1914	90	1904	91	1909	92
California	25.1	1897–1930	1898	42	1923	57	1929	61	1917	66	1910	67	1924	69	1930	72	1928	75	1908	75	1897	77
Colorado	16.8	1888–1930	1888	72	1890	72	1893	78	1889	83	1924	84	1903	84	1902	84	1901	86	1900	87	1894	87
Florida	52.5	1892–1930	1927	78	1917	79	1921	87	1895	88	1916	88	1911	90	1913	92	1892	92	1901	92	1898	93
Georgia	49.6	1892–1930	1904	75	1893	82	1927	83	1921	83	1910	88	1916	88	1899	89	1896	91	1914	92	1930	93
Idaho	17.1	1898–1930	1924	74	1929	78	1928	81	1898	83	1904	87	1901	91	1922	91	1905	92	1900	95	1914	95
Illinois	36.4	1878–1930	1901	71	1930	77	1894	80	1914	82	1895	88	1910	88	1879	90	1917	90	1920	91	1925	90
Indiana	39.3	1887–1930	1930	76	1901	79	1895	79	1914	80	1894	82	1908	88	1925	89	1899	90	1889	92	1887	93
Iowa	31.8	1873–1930	1910	63	1894	69	1901	78	1886	78	1889	79	1930	84	1887	84	1895	85	1897	85	1917	88
Kansas	26.8	1887–1930	1917	74	1910	74	1893	75	1894	77	1890	80	1901	80	1913	86	1914	85	1916	90	1921	90
Kentucky	45.1	1889–1930	1930	63	1894	77	1901	79	1901	79	1889	81	1895	85	1918	91	1925	91	1903	91	1914	93
Louisiana	55.3	1891–1930	1924	70	1917	72	1899	77	1904	80	1902	84	1896	85	1921	87	1906	88	1910	89	1903	91
Maryland and Delaware	41.5	1895–1930	1930	56	1895	83	1925	85	1914	87	1904	88	1900	88	1896	89	1910	91	1909	91	1921	92
Michigan	30.5	1888–1930	1930	75	1925	84	1910	84	1889	89	1917	90	1895	93	1894	93	1901	93	1899	94	1923	95
Minnesota	25.7	1886–1930	1910	57	1889	74	1923	78	1929	81	1917	85	1894	84	1912	88	1930	88	1921	90	1887	93
Mississippi	53.2	1888–1930	1889	72	1924	75	1904	79	1896	82	1899	85	1914	88	1930	89	1910	89	1894	90	1895	91
Missouri	40.5	1888–1930	1901	62	1930	77	1894	82	1914	86	1890	88	1910	92	1899	93	1906	93	1918	93	1913	94
Montana	15.4	1895–1930	1904	73	1919	73	1930	80	1895	86	1928	86	1929	86	1900	88	1924	89	1926	91	1918	91
Nebraska	23.5	1876–1930	1894	58	1893	72	1890	74	1910	74	1895	80	1916	81	1899	83	1922	87	1907	87	1898	89
Nevada	8.2	1890–1930	1928	60	1924	69	1910	69	1929	71	1926	80	1898	81	1917	82	1903	87	1919	87	1902	88
New England	41.9	1888–1930	1930	83	1914	84	1910	85	1924	85	1908	85	1894	87	1905	89	1921	89	1911	94	1892	94
New Jersey	46.2	1885–1930	1930	78	1895	81	1918	81	1885	83	1916	83	1921	83	1914	86	1910	86	1923	88	1917	89
New Mexico	14.9	1892–1930	1910	64	1917	64	1892	64	1902	68	1894	72	1924	72	1922	74	1899	74	1903	74	1893	84
New York	39.4	1890–1930	1930	82	1908	85	1895	86	1899	88	1921	91	1923	91	1909	92	1911	93	1914	93	1910	95
North Carolina	50.1	1887–1930	1925	75	1930	77	1911	86	1921	86	1904	87	1926	87	1902	90	1923	90	1897	93	1890	94
North Dakota	17.9	1892–1930	1917	61	1910	69	1929	80	1907	82	1930	83	1913	83	1898	85	1920	87	1894	88	1893	89
Ohio	38.2	1883–1930	1930	71	1895	75	1894	79	1901	86	1900	87	1889	87	1887	88	1925	90	1899	91	1928	92
Oklahoma	32.5	1893–1930	1910	60	1917	69	1901	71	1896	73	1893	80	1894	80	1914	80	1909	84	1924	87	1925	88
Oregon	30.6	1890–1930	1910	60	1917	69	1930	71	1901	71	1896	73	1893	79	1894	80	1914	80	1909	84	1922	87
Pennsylvania	42.4	1888–1930	1930	68	1895	80	1922	83	1900	88	1909	88	1925	89	1910	92	1923	92	1908	93	1904	95
South Carolina	48.3	1887–1930	1925	74	1911	82	1930	84	1904	86	1927	87	1914	91	1887	91	1917	91	1916	92	1909	92
South Dakota	20.8	1890–1930	1894	75	1910	75	1925	77	1895	77	1890	79	1898	79	1917	81	1926	86	1893	87	1930	88
Tennessee	50.1	1884–1930	1930	80	1925	82	1904	82	1894	86	1895	87	1914	89	1885	90	1887	91	1889	92	1908	92
Texas	31.1	1891–1930	1917	53	1893	66	1910	70	1901	72	1909	75	1924	76	1916	80	1925	83	1912	84	1897	89
Utah	13.5	1892–1930	1900	63	1902	69	1892	72	1901	75	1903	77	1898	80	1924	80	1895	80	1928	80	1910	83
Virginia	42.4	1892–1930	1930	59	1925	77	1921	83	1894	85	1904	85	1914	88	1895	91	1912	92	1900	92	1916	93
Washington	36.1	1890–1930	1929	66	1922	68	1911	73	1930	76	1924	78	1925	79	1923	82	1918	84	1913	84	1904	87
West Virginia	43.2	1891–1930	1930	59	1895	76	1904	78	1894	81	1892	89	1900	88	1892	89	1910	89	1914	92	1893	92
Wisconsin	30.6	1891–1930	1910	70	1902	76	1895	77	1930	82	1891	86	1901	86	1923	87	1894	88	1917	89	1925	90
Wyoming	14.6	1899–1930	1902	68	1919	72	1900	77	1910	83	1901	83	1921	87	1914	87	1924	87	1916	88	1903	88
Means	------	------	------	68	------	75	------	78	------	82	------	83	------	85	------	86	------	88	------	89	------	93
NEW ENGLAND STATIONS																						
New Bedford, Mass	46.2	1814–1930	1930	61	1923	68	1919	71	1921	71	1918	71	1846	75	1849	80	1885	81	1856	81	1910	82
Boston, Mass	43.7	1818–1930	1822	63	1846	69	1908	70	1905	73	1837	77	1887	77	1923	78	1930	82	1825	82	1819	82
Lowell, Mass	41.5	1826–1930	1914	67	1846	67	1910	69	1837	74	1908	75	1930	75	1834	76	1835	79	1894	81	1891	82
Amherst, Mass	44.2	1836–1930	1908	70	1924	71	1894	74	1930	74	1864	79	1846	79	1880	81	1843	86	1850	88	1912	88
Providence, R. I	44.2	1832–1930	1914	76	1846	70	1835	70	1930	70	1837	72	1909	77	1915	77	1910	77	1916	79	1849	79

TABLE 2.—*Years of greater than normal precipitation in the United States arranged by States and expressed in percentage of normal*

States	1		2		3		4		5		6		7		8		9		10	
	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent
Alabama	1929	147	1900	126	1919	124	1920	124	1926	117	1923	117	1922	112	1909	111	1888	110	1892	109
Arizona	1905	193	1919	142	1916	124	1923	124	1914	124	1926	121	1906	116	1908	114	1927	114	1915	114
Arkansas	1927	138	1905	133	1923	125	1892	121	1906	120	1898	120	1919	115	1920	115	1913	113	1915	112
California	1923	127	1909	125	1927	121	1891	120	1906	118	1897	117	1915	117	1921	117	1911	115	1914	115
Colorado	1909	169	1906	155	1916	140	1915	136	1907	130	1914	124	1904	122	1911	118	1922	116	1926	108
Florida	1912	124	1924	117	1905	117	1900	116	1928	116	1926	115	1929	112	1920	111	1922	110	1919	110
Georgia	1929	141	1912	128	1928	121	1920	120	1901	116	1900	116	1922	112	1919	112	1906	112	1924	110
Idaho	1927	134	1909	130	1912	127	1906	122	1916	122	1907	120	1917	119	1913	117	1915	113	1925	112
Illinois	1927	136	1882	132	1883	130	1898	129	1881	121	1884	119	1909	119	1926	119	1902	116	1915	116
Indiana	1890	126	1927	125	1909	123	1929	120	1898	117	1907	114	1913	112	1920	111	1905	110	1923	109
Iowa	1881	139	1902	139	1909	127	1915	124	1896	117	1919	117	1876	116	1892	116	1928	113	1884	112
Kansas	1915	152	1902	128	1928	125	1927	121	1908	121	1923	121	1898	120	1903	118	1909	117	1891	116
Kentucky	1890	130	1923	120	1927	118	1898	116	1919	116	1915	116	1909	114	1910	112	1926	112	1891	110
Louisiana	1905	139	1923	129	1919	125	1922	121	1926	119	1900	119	1912	117	1913	117	1929	116	1920	114
Maryland and Delaware	1902	119	1907	119	1906	116	1919	115	1903	114	1924	112	1901	109	1928	109	1926	107	1905	106
Michigan	1893	114	1911	114	1890	113	1916	112	1892	110	1905	109	1928	109	1926	108	1903	107	1902	107
Minnesota	1905	130	1903	129	1906	123	1896	122	1899	118	1900	116	1904	116	1908	116	1902	116	1909	115
Mississippi	1923	134	1919	131	1900	125	1912	125	1905	123	1920	119	1929	113	1911	113	1922	112	1909	110
Missouri	1927	134	1898	133	1915	122	1929	116	1928	113	1905	113	1909	112	1902	112	1896	111	1921	108
Montana	1927	134	1908	132	1909	128	1915	123	1916	123	1911	121	1906	121	1923	119	1896	115	1912	113
Nebraska	1915	152	1905	135	1881	132	1883	132	1891	131	1902	124	1923	120	1903	117	1906	115	1908	115
Nevada	1906	194	1891	174	1901	161	1907	160	1890	159	1909	136	1913	136	1894	135	1896	131	1904	131
New England	1888	134	1898	122	1890	121	1889	118	1920	116	1901	115	1902	112	1897	112	1900	110	1927	110
New Jersey	1889	138	1902	128	1903	121	1898	113	1888	113	1919	113	1920	112	1907	112	1901	112	1897	112
New Mexico	1919	141	1905	141	1923	131	1914	131	1911	121	1915	119	1926	117	1897	111	1921	111	1929	111
New York	1890	126	1927	115	1892	111	1898	111	1903	110	1901	110	1902	109	1929	109	1893	108	1925	106
North Carolina	1901	125	1929	124	1906	119	1908	115	1922	114	1920	113	1928	112	1888	110	1891	109	1924	109
North Dakota	1896	132	1927	121	1916	116	1912	113	1905	112	1908	112	1906	111	1921	111	1901	109	1915	109
Ohio	1890	132	1929	120	1883	119	1913	118	1898	115	1926	115	1921	113	1927	113	1907	113	1909	113
Oklahoma	1908	156	1915	140	1923	138	1902	125	1905	123	1927	122	1926	120	1905	112	1928	112	1920	112
Oregon	1896	183	1894	166	1893	160	1899	157	1902	151	1904	149	1891	147	1897	143	1895	143	1907	137
Pennsylvania	1889	124	1890	121	1902	112	1927	112	1919	111	1903	110	1888	109	1891	108	1898	108	1901	108
South Carolina	1929	138	1928	128	1922	121	1924	119	1901	115	1906	114	1888	114	1912	114	1893	111	1908	111
South Dakota	1915	142	1906	140	1920	137	1905	133	1908	125	1892	121	1896	119	1909	118	1927	115	1900	114
Tennessee	1929	119	1890	115	1923	115	1919	115	1920	113	1884	111	1912	109	1922	109	1926	109	1892	108
Texas	1919	147	1900	137	1905	135	1923	129	1914	122	1926	118	1913	117	1920	110	1907	110	1902	110
Utah	1909	149	1906	140	1920	127	1927	127	1921	126	1907	123	1916	123	1908	113	1922	113	1897	113
Virginia	1902	121	1901	118	1906	117	1924	113	1893	110	1920	109	1929	109	1908	106	1903	106	1922	106
Washington	1896	128	1894	120	1891	120	1899	117	1902	117	1927	117	1893	115	1897	110	1900	104	1909	99
West Virginia	1907	122	1926	116	1913	113	1927	113	1924	110	1898	110	1919	110	1911	110	1929	107	1891	107
Wisconsin	1911	121	1903	117	1905	117	1906	117	1926	116	1892	115	1900	114	1916	111	1919	109	1928	108
Wyoming	1915	133	1923	133	1912	127	1927	125	1906	122	1908	120	1909	113	1905	111	1918	111	1913	111
Means	------	139	------	130	------	125	------	122	------	119	------	117	------	116	------	116	------	113	------	112
New Bedford, Mass, 1814–1929	1829	142	1830	141	1827	136	1850	136	1898	136	1890	134	1831	133	1823	130	1868	123	1888	120

The chief interest in the two tables is historic; the data in them will serve as a reference point for future studies of excess or deficit in annual precipitation.

Obviously the percentage of the normal that is received in the dry regions of the Southwest is less than for the humid sections east of the Mississippi; somewhat unexpected results are the relatively low percentage of rain that is received in dry years in California, Oregon, and Washington, the range being from 42 per cent in California to 66 per cent in Washington. In Arizona and parts of New Mexico low percentages were to be expected. Arizona, especially the lowlands of the western portion, occasionally receives in very dry years at individual stations less than 1 per cent of the average annual precipitation. At the higher levels individual stations receive nearly as great a percentage of the annual as do points situated in the humid regions of the East. The percentage of the annual precipitation received by the Rocky Mountain States of Colorado, Idaho, and Montana is greater than was expected. Florida in the South, Indiana and Michigan in the North, and New York and New England in the Northeast show the greatest stability, or in other words less percentage variation than in other places in the humid region. The New England record as given in Table 1 depends on the observations for the period 1888–1930; if, however, the individual stations having from 50 to 100 years of observations be considered smaller percentages will be found to obtain; thus for the driest, second, and third driest the percentages were 66, 69, and 71, respectively. (See records of five individual long-record stations at bottom of Table 1.)

The data of Table 1 establishes the fact that the year 1930 set the record for extreme dryness in the United States as a whole; the States of Maryland and Delaware, the two Virginias, Kentucky, and Ohio standing in the order named with respect to the percentage of the normal precipitation that was received. The drought of 1901 in Missouri, those of 1910 in Iowa, 1917 in North Dakota, Texas, and possibly other parts of the country, were more intense, precipitation being considered, than in 1930.

Following is a comparison of the average percentage of the normal precipitation in all recorded droughts as shown at the bottom of Table 1 with that of England and Wales in the five driest years in Great Britain.[1]

	Per cent
United States, average of all droughts	68
England and Wales, drought of—	
1921	71
1887	74
1854	77
1864	78
1870	82

It is of additional interest to observe that while drought in the United States is not always synchronous with drought in the British Isles it is more so than would be required by chance. The year of greatest drought in Britain—1921—was also a warm and droughty year in the United States, the second greatest drought in Britain—1887—was droughty in some sections but was not so severe and general as in 1886, the year previous; 1854–55 and 1856–57 were all more or less droughty years in this country, but the droughts were local in character rather than general and this is also the case in the early seventies.

As has been found in earlier studies of the precipitation in the United States[2] the fact that the smaller the average rainfall the greater is the variation from year to year is again confirmed; for this and other reasons the actual precipitation in Tables 1 and 2 is given as a percentage of the normal for the section. There are several more or less distinct groups of rainfall distribution in the United States; following is a rather coarse grouping:

1. The Pacific coast and Plateau States, embracing Washington, Oregon, California, Nevada, Utah, Arizona, and New Mexico. This group is characterized by the greatest annual variation in precipitation to be found in continental United States.
2. The Plains States of North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, Missouri, Iowa, and Minnesota. The three last named while not strictly Great Plains States may be included in that group because of similar rainfall distribution. They form the largest group and are characterized by what may be called the continental type of rainfall distribution.
3. The Gulf States of Louisiana, Mississippi, Alabama, and Florida. This group receives a greater precipitation than either of the two first mentioned and the annual rainfall may be said to be much more dependable; that is, it varies less from the normal.
4. Finally the group of Northeastern States have the most dependable precipitation of any part of the United States. I include in this group New England, New York, New Jersey, Pennsylvania, and Michigan.

In Table 3 will be found a summary showing the percentage of the annual precipitation for the driest year, the second and third driest on the average of each group. Likewise the average percentage of the greatest, the second, and third greatest is also shown.

TABLE 3.—*Percentage of the average precipitation in the three years of deficient and the three years of greatest precipitation in the groups of States numbered 1 to 4 on the left of the table*

Groups	Least			Greatest			Range
	1	2	3	1	2	3	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
No. 1	59	65	67	167	149	136	108
No. 2	64	72	77	143	133	129	79
No. 3	74	77	82	136	126	123	62
No. 4	78	83	84	127	120	116	49

The sequence of dry years, Figure 1.—The data of Table No. 1 have been summarized and reproduced as Figure 1, in order to show graphically the sequence and grouping of the dry years; column 1 of that figure shows, as previously explained the number of sections, if any, in which the least annual precipitation of the whole series of years was recorded; column 2 the number in which the next to the least was recorded; and so on, so that the series of steps to the right of column 1 may be considered as a series of annual precipitation amounts which approach but do not reach the normal.

The full lines in the figure show those years that may be considered as falling within the group of major dry years. These are 1889, 1894, 1901, 1910, 1917, 1921, 1924, and 1930. There is a slight tendency in the groups to spread fan shaped toward the right, thus indicating that the peak dry year is preceded in most cases by gradually diminishing precipitation during one or two years prior to that year, thus the peak dry year of 1894 was preceded by diminishing precipitation in 1892 and 1893 and was followed by somewhat dry years in 1896–97. This is merely another way of saying that severe droughts gradually approach a peak year and that the return of normal conditions is brought about gradually.

[1] Quart. Jour. Roy. Met. Soc. 48: 140.
[2] Henry, Alfred J. Rainfall of the United States, Weather Bureau Bulletin D, Washington, 1897.

DRY YEARS - SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1879							1				1
85				1			1				2
86				1							1
87							3	1		2	6
88	1										1
89	1	3		2	2	1			2		11
90		1	1		3					1	6
91					1						1
92			2		1		1	1		1	6
93		3	2		1	1			1	3	11
94	2	2	3	4	2	3	2	1	2	2	23
95		5	3	3	3	2	1	2		1	20
96			1	2	2	1	1	1			8
97									3	2	5
98	1			1		3	1			2	8
99			1	1	2		3	2	2		11
1900	2		1	1	1	2	1		3		11
1	3	1	2	5	1	3		2	1		18
2	1	2		1	1		2	1		1	9
3					1	1	1	1	2	2	8
4	3		4	2	4	1			2	2	18
5							1	1			2
6								2			2
7				1					1		2
8		1			1	1			2	1	6
9					2		1	1	2	2	8
10	6	3	4	3	2	3	1	4	1	2	29
11		1	2			1		1	1		6
12							1	1	1		3
13						1	2		1	1	5
14		1	1	4		4	3	3	3	2	21
16					2	2	2		3	1	10
17	3	5		2	2		2	2	1	2	19
18			1				1	1	1	1	5
19		2							1		3
20								1	1		2
21			2	3	1	2	1	1	1	2	13
22		1	1				2	1		1	6
23		1	1			1	2	2	1	1	9
24	2	3	1	1	2	3	1	3	1		17
25	2	3	2			3	1	3		3	17
26					1	1		1	1		4
27	1		1		1						3
28	1		1		2			1	1	1	7
29	1	1	2	2		1				1	8
30	12	3	3	2	1	1	3	1		2	28
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 1.—Chronological list of years with deficient precipitation on a scale of 1 to 10. (See text)

WET YEARS - SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1876							1				1
81	1		1		1						3
82		1									1
83			2	1							3
84						2				1	3
88	1				1		2	1	1		6
89	2			1							3
90	4	2	2		1						9
91		1	1	1	1		1	1	1	3	10
92			1	1	1	2		1	1	2	9
93	1		1		1		1				4
94		2	–					1	1		4
96	3			1	1		1				6
97						1		4	4	2	11
98		2		4	2	2	1				11
99				2	1						3
1900		2	1	1		3	1			1	9
1	1	1	1		2	2	1			1	9
2	2	3	1	1	2	1	2	1	1	2	16
3		2	1		2	1		2	2		10
4						1	2			1	4
5	3	3	3	1	3	2		2	2	1	20
6	1	3	4	2	3	1	3				17
7	1	1		1	1	3		1	1	1	10
8	1	1		1	2	2		4	4	2	17
9	2	2	3			1	4	2	2	4	20
10								1	1		2
11	1	1			1	1		3	3		10
12	1	1	2	2			2	1	1	1	11
13			1	1			3	2	2	1	10
14				1	2	1				1	5
15	4	1	1	3		2	1			4	16
16			3	1	2		1	1	1		9
17							1				1
19	2	2	2	2	2	2	2	1	1	1	17
20			2	2	2	3	1	3	3	2	18
21					1		1	2	2	1	7
22			1	1	1		2	1	1	1	8
23	2	3	4	2		2	1	1	1	1	17
24		1		2	1	1				2	7
25										2	2
26		1			3	4	2	3	3	1	17
27	5	3	2	5		2		1	1	1	20
28		1	2		2		2	1	1	1	10
29	4	2		2			3	1	1	1	14
30											0
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 2.—Chronological list of years with greater than the normal precipitation. (See text)

The dry year 1910 is seemingly in a class by itself, as is also 1917. The onset of the first named was quite sudden as compared with the others shown in the figure. The year 1917 was one of maximum spottedness of the sun and that fact has been used by some in an effort to tie up the occurrence of droughts with the occurrence of many sun spots; the difficulty that must be faced by them is that the record shows that droughts occur almost simultaneously with both increasing and diminishing sun-spot numbers. (See Table 4.)

TABLE 4.—*Droughts in the United States and sun spots*

Year	Sun-spot curve		Smoothed sun-spot numbers			Nearest epoch of—	
	Rising	Falling	January	December	Year	Minimum	Maximum
1854		F	28.2	15.6	21.0	1856.0	
1856	R		3.3	9.3	5.2	1856.0	
1857	R		10.5	36.0	23.0	1856.0	
1860		F	97.2	90.6	94.8		1860.1
1863		F	51.9	43.2	45.4		1860.1
1864	R [1]	F	41.8	41.3	45.2	1867.2	
1870	R		110.0	135.4	131.8		1870.6
1881	R		47.0	62.4	54.4	1878.9	
1893	R		78.0	86.7	83.7		1894.1
1894		F	87.9	71.3	79.1		1894.1
1895		F	67.7	52.5	61.5		1894.1
1901		F	4.8	2.8	3.4	1901.7	
1910		F [2]	31.5	12.8	21.0	1913.6	
1916	R		57.8	68.7	59.1		1917.6
1917	R		73.4	98.3	96.2		1917.6
1924	R		0.5	16.5	16.7	1923.6	
1930		F	63.7	28.0			1928.0

[1] Rising followed by falling.
[2] The driest year in the United States in forty-odd years.

The 1924-25 drought had its beginning in 1921 and was distinguishable as late as 1926, although in that year a number of States had more than the average precipitation. It happens, not infrequently, that one and the same year may yield abundant rain in one part of the country and withhold it in another, as illustrated by 1927, the year of the great Mississippi flood. In that year Florida, Georgia, and South Carolina suffered more or less from drought.

YEARS OF GREATEST PRECIPITATION

The chronological record of years with greater than the normal precipitation as summarized from the data of Table 2 is presented in Figure 2. In that figure I have indicated the probable grouping of years of greater than the normal precipitation by inclosing them in continuous lines. These years occur also in groups as in the case of years of deficient rainfall. The groups are centered about 1890, 1898, 1902, 1905, 1909, 1912, 1915, 1919, 1923, and finally in 1927, 1928, and 1929.

The average interval between these dates is roughly four years.

If the figures of the extreme right-hand column of Tables 3 and 4 be smoothed by the formula $\left(\frac{a+2b+c}{4}\right)$ and the smoothed values be plotted against time as abscissa the resulting curve indicates a period of approximately four years between epochs of maximum and minimum. I attach no great importance to these curves, since the smoothing process distorts or rather displaces the epochs of maximum and minimum and reduces the amplitude of the oscillations.

Figure 2 is complementary to Figure 1, since it presents the grouping of the opposite extreme in the annual precipitation. Viewing the two figures one must be struck with the apparent absence of chance in the annual distribution of precipitation; rather these two figures favor the idea that the years of little and much rainfall succeed each other in a wave like sort of motion which advance from west to east and perhaps in due course encircle the globe. It is also possible to identify in them the well-known Brückner years of dry and wet weather said to repeat themselves in a period of 35 years.

Another outstanding feature to which attention is invited is that years of drought do not come suddenly and unheralded but almost uniformly preceded by one or two years of diminished precipitation in various parts of the United States; likewise peak dry years are sometimes followed immediately by one or two years of fairly good rains apparently intercalated in a series of dry years as in 1902-03 and again in 1915-16.

Conclusions.—The facts hereinbefore presented lead to the belief that in the great majority of cases the total annual precipitation may be used as a criterion on drought; it must, however, be used intelligently, bearing in mind that the area under consideration with up to 70 per cent of its annual normal rainfall may have been very dry in spots but as whole the deficit may not have been equally pronounced.

In the Pacific coast and Plateau States any one year with but 60 per cent of its annual precipitation may be classed as a dry year. In the Great Plains States, excepting South Dakota, 65 per cent, while not as low as has been reached in past droughts may be accepted as a measure of severe drought. In the Gulf States the range is from 70 to 75 per cent and in the Northeastern States the lower limit is from 75 to 85 per cent.

SOLAR RADIATION INTENSITIES WITHIN THE ARCTIC CIRCLE

By HERBERT H. KIMBALL

[Weather Bureau, Washington, D. C., April 15, 1931]

In summaries of solar radiation measurements prepared by the author,[1] the following stations within, or practically on the Arctic Circle have been listed:

Abisko, Sweden, latitude 68° 21′ N., longitude 18° 49′ E., altitude 390 meters.

Jokkmokk, Sweden, latitude 66° 36′ N., longitude 19° 51′ E., altitude 255 meters.

Mount Evans, Greenland, latitude 66° 51′ N., longitude 50° 50′ W., altitude 394 meters.

Rovaniemi, Finland, latitude 66° 29′ N., longitude 25° 44′ E., altitude 200 meters.

Treurenberg, Spitzbergen, latitude 79° 55′ N., longitude 16° 52′ E., altitude 9 meters.

At these stations solar radiation intensity at normal incidence was measured. Now we may add to the above list Green Harbor, Spitzbergen, latitude 78° 00′ N., longitude 14° 05′ E., with continuous measurements of the total solar radiation (direct+diffuse) received on a horizontal surface.

SOLAR RADIATION MEASUREMENTS AT GREEN HARBOR, SPITZBERGEN

At the second general assembly of the International Geodetic and Geophysical Union at Madrid, in 1924, the

[1] Measurements of solar radiation itensity and determinations of its depletion by the atmosphere. MONTHLY WEATHER REVIEW, 55: 155, April, 1927, 58: 43, February, 1930.

Meteorological Section set aside the sum of £400 for the purchase of self-recording pyrheliometers or pyrgeometers for use in northern Canada or Spitzbergen, New Zealand or Samoa, Brazil or Belgian Congo, and the South Orkneys.

For Spitzbergen a Gorczyński recording solarimeter was obtained, and was installed by Dr. H. U. Sverdrup at Green Harbor at the beginning of September, 1927. The instrument is designed to give a continuous record of the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky. In transmitting a summary of the measurements Doctor Sverdrup makes the following statement:

> These records have been obtained by means of a Gorczyński recording instrument which was delivered by Kipp & Zonen, and installed by myself at the Norwegian radio station. The records have been reduced at the Geophysical Institute in Bergen, using the constant for the instrument which was obtained from the makers. This constant, according to comparisons with records from Finland, can be regarded as fairly accurate. No absolute observations were undertaken at Green Harbor, since there was no trained observer at the station.

As tabulated at Bergen the average intensity of solar radiation is given for each hour of each day, central on the full hour. The maximum intensity for each day is also given. From the latitude of Green Harbor, and neglecting atmospheric refraction, we would expect the sun to appear above the southern horizon on February 17 and to disappear below it on October 25. Actually, the first sunshine in spring was recorded on February 26 and the last in fall on October 18. Also, we would expect solar radiation throughout the 24 hours from April 21 to August 21. Actually, the first day in spring with solar radiation during every hour is April 29, although recorded at midnight after the 25th. The sun was continuously above the horizon on August 9 when the record ended.

TABLE 1.—*Total solar radiation (direct+difuse) measured at Green Harbor, Svalbard. Latitude 78° 00′ N., longitude 14° 05′ E.*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily	Maximum daily	Maximum hourly	Maximum per minute
1927	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 4 [1]	131	184	26	0.55
Sept. 10	107	135	20	0.38
Sept. 17	56	72	13	0.33
Sept. 24	45	68	14	0.19
Oct. 1	15	17	4	0.14
Oct. 8	12	19	5	0.12
Oct. 15 [2]	5	7	3	0.05
1928				
Feb. 26	7	11	3	0.06
Mar. 4	18	27	5	0.12
Mar. 11	43	50	8	0.21
Mar. 18	75	86	13	0.24
Mar. 25	101	131	19	0.38
Apr. 1	133	185	23	0.41
Apr. 8	180	216	26	0.58
Apr. 15	233	301	31	0.69
Apr. 22	320	373	35	0.83
Apr. 29	303	355	37	0.83
May 6	428	447	43	0.92
May 13	450	502	44	0.91
May 20	445	517	50	1.10
May 27	505	521	46	1.09
June 3	447	592	47	0.91
June 10	562	[5] 652	53	1.43
June 17	615	644	49	0.85
June 24 [3]	562	643	49	0.81
July 2	480	622	51	1.03
July 9	296	506	46	1.07
July 16	358	536	44	0.90
July 23	340	443	40	0.73
July 30	340	416	38	0.76
Aug. 6 [4]	273	365	33	0.66

[1] 6 days only. [2] 4 days only. [3] 8 days. [4] 4 days only.
[5] The sum of maximum hourly amounts for the respective hours=712 gr. cals.

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In Table 1 the data as originally tabulated have been summarized by weeks, giving for each week the average daily amount of radiation expressed in gram-calories per square centimeter of horizontal surface, and also the maximum per day, per hour, and per minute. There are frequent gaps in the record, especially at about 8 a. m. The average daily amounts are based on such data as has been furnished, with interpolations where practicable.

In June the maximum total is less than that computed by me for June 21 with cloudless sky at Latitude 60° and 90° north, and the average daily total is greater.[2] From this I conclude that at Green Harbor in June one does not often find 24 hours with skies continuously free from clouds and fog, and that, on the other hand, the average cloudiness is not as great as has been observed at other Arctic stations, or at least that this was the case in 1928.

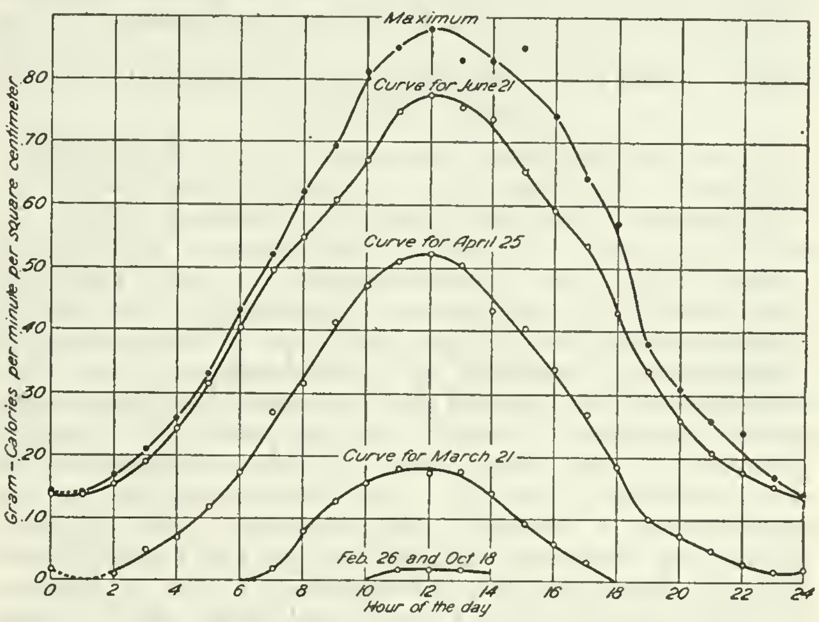

FIG. 1.—Diurnal march of solar radiation at Green Harbor, Spitzbergen, for different epochs of the year. (The time scale is on apparent, or true solar time.)

Without having seen the original record sheets, there appears to be some question about the accuracy of the maximum radiation per minute (1.43 gram-calories) recorded on June 10. At noon on this day the solar altitude was only slightly in excess of 35°. The intensity of direct solar radiation could hardly have exceeded 1.5 gram-calories per minute per square centimeter, and its vertical component would be $1.50 \times 0.574 = 0.86$, leaving 0.57 gram-calories per minute per square centimeter for sky radiation. This amount could have been received only under the most favorable conditions for reflection of light from clouds between the sun and the zenith. A well-authenticated increase in the intensity of solar radiation of 20 per cent due to reflection from clouds occurred at Mount Weather, Va., on July 28, 1912.[3] The percentage increase at Green Harbor appears to have been considerably greater, or from 25 to 30 per cent. Possibly reflection from the snow and ice covered ground surface to the under side of the cloud and then back to the earth would account for the excessively high radiation intensity in question.

In Figure 1 the diurnal march of radiation is represented by the hourly intensities for the first day in spring and the last day in autumn on which records were ob-

[2] Kimball, Herbert H. Amount of solar radiation that reaches the surface of the earth on the land and on the sea, and methods by which it is measured. MONTHLY WEATHER REVIEW, vol. 56:393, 1928.

[3] Kimball, Herbert H., and Miller, Eric. The Influence of Clouds on the Distribution of Solar Radiation. Bull. Mt. Weather Obs., 5:166, 1912.

tained, by the hourly averages for March 18–24, the week of the vernal equinox, for April 22–28, the first week on which radiation was recorded at midnight, for June 17–23, the week of the summer solstice, and finally a curve representing the maximum average hourly intensities recorded in each of the 24 hours. The sum of these last-named hourly averages multiplied by 60 gives the maximum daily radiation with clear skies for the year.

It is to be noted that the average daily amount for the three weeks centering on the summer solstice is greater than the average of the daily normals for this period for any stations in the United States except Twin Falls, Idaho, and Fresno, Calif., as given in Table 4, MONTHLY WEATHER REVIEW for February, 1930, volume 58, page 45.

What must be the effect upon plant and animal life of this stimulus of continuous solar radiant energy during four months of the year? In lower latitudes it has been found that generally plants as well as animals require the night hours of rest for their best development.

SOLAR RADIATION MEASUREMENTS MADE AT MOUNT EVANS, GREENLAND

These measurements were made by C. R. Kallquist and Prof. J. E. Church, jr., members of the University of Michigan Greenland Expedition, between August 13, 1927, and April 17, 1928, which covers a part of the period during which measurements of solar radiation were made at Green Harbor, Spitzbergen. The instrument employed was of the Moll type of thermoelectric pyrheliometer, mounted in a diaphragmed tube, with attachments that enabled the observer to keep the instrument accurately pointed on the sun. The current generated by the heating effect of solar radiation on the free junction of the pile was determined by an eye reading on a Weston millivoltmeter. The pyrheliometer was carefully standardized at the United States Weather Bureau before the departure of the expedition, to determine the e. m. f. developed in the pile by solar radiation of known intensity. It was hoped to recalibrate the instrument after its return from Greenland. Unfortunately, however, while the pyrheliometer was received back in excellent condition the millivoltmeter was ruined by the upsetting of a boat in which it was being transported. A satisfactory recalibration of the complete apparatus was therefore impossible.

A brief summary of these measurements was given by me in a paper in the Review for February, 1930.[4] They are here summarized in more detail.

TABLE 2.—*Pyrheliometric readings made by Prof. J. E. Church, jr., during trip to and on inland ice. Direction of travel, east from latitude 66° 50′ N., longitude 51° W., total distance, 30 miles*

[Gram-calories per minute per square centimeter of normal surface]

Date	Air mass									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1927	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 13, a. m.	1.43	1.32	1.20							
Aug. 13, p. m.		1.33	1.23	1.15	1.07	1.00	0.94	0.88	0.84	0.80
Aug. 14, a. m.	1.44	1.35	1.26							
Aug. 14, p. m.		1.33	1.24	1.16	1.08	1.02	0.96	0.91	0.86	0.81
Aug. 15, a. m.	1.45	1.33	1.23	1.16	1.09	1.03				
Aug. 15, p. m.		1.33	1.23	1.12	1.03	0.95	0.89	0.86	0.84	0.82
Aug. 16, a. m.	1.30	1.22	1.16	1.09	1.02	0.96	0.91			
Aug. 16, p. m.			1.16	1.10						
Aug. 17, a. m.	1.40	1.32	1.25	1.18	1.12	1.07	1.04	1.01	0.98	0.97
Aug. 17, p. m.		1.34	1.21	1.10						
Aug. 20, a. m.	1.38	1.29	1.20	1.14	1.08	1.04	1.00	0.96		
Means	1.40	1.32	1.22	1.13	1.07	1.01	0.96	0.92	0.88	0.85

[4] Kimball, Herbert H. Measurements of solar radiation intensity and determinations of its depletion by the atmosphere. Monthly Weather Review. 58:43.

Table 2 summarizes measurements made by Professor Church, between August 13 and 16, inclusive, on the journey from the shore to the inland ice, at altitude of from 250 to 450 feet above sea level; on August 17 at the edge of the ice where the altitude was about 950 feet and on August 20 on the inland ice, at an altitude of between 1,600 and 1,800 feet. The distance covered was about 30 miles, and the direction traveled was approximately east, so that there was little change in latitude. The change of correction necessary to reduce forty-fifth meridian time to apparent time was taken into account in computing solar altitudes corresponding to the time at which the measurements were made. Solar altitudes at noon varied from 37° 45′ on August 13 to 35° 32′ on August 20, corresponding to air masses 1.63 and 1.72, respectively. The intensities for air mass 1.5 and 1.0 were therefore obtained by extrapolation.

Table 3 summarizes measurements made by C. R. Kallquist at Mount Evans, Greenland, on the inland ice, at an altitude of 1,228 feet (374 meters). Slight extrapolations have in a few cases been necessary to obtain the intensities tabulated. In general, the readings indicate a very pure and dry atmosphere, as is shown by the values for the atmospheric transmission given in Table 4.

TABLE 3.—*Pyrheliometric readings made by C. R. Kallquist at Mount Evans, Greenland. Latitude 66° 51′ N., longitude 50° 50′ W., altitude 1,228 feet*

[Gram-calories per minute per square centimeter of normal surface]

Date	Solar altitude												Vapor pressure
	30.0°	23.5°	19.3°	16.4°	14.3°	11.3°	9.3°	7.8°	6.8°	3.1°	1.8°	0.7°	
	Air mass												
	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	15.0	21.0	30.0	
1927	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 6, p. m.	1.32	1.26	1.20										4.75
Sept. 7, p. m.	1.31	1.26											4.37
Sept. 17, p. m.		1.34	1.25	1.19	1.15	1.08	1.01			0.42			
Sept. 18, p. m.		1.30	1.24	1.19	1.14	1.07	1.02				0.62		
Sept. 20, p. m.		1.40	1.23	1.22						0.65			2.74
Sept. 22, p. m.				1.18	1.14	1.08							
Sept. 24, p. m.		1.31	1.25	1.20									2.62
Sept. 25, p. m.			1.30	1.22	1.18	1.11							2.74
Means	1.32	1.31	1.25	1.20	1.15	1.08	1.02			0.54	0.62		3.44
Oct. 12, a. m.				1.28	1.21	1.10	1.03						2.16
Oct. 12, p. m.				1.22	1.16	1.06							
Means				1.25	1.18	1.08	1.03						
1928													
Feb. 18, p. m.						1.25	1.14	1.10	1.09	0.76		0.27	0.38
Mar. 20, a. m.		1.47	1.39	1.34	1.30								0.51
Mar. 20, p. m.		1.56	1.39		1.32	1.18	1.07						
Means		1.52	1.39	1.34	1.31	1.18	1.07						
Apr. 3, a. m.	1.47	1.38	1.30	1.22									1.52
Apr. 3, p. m.	1.50	1.38	1.29	1.24	1.19								
Apr. 4, a. m.	1.44	1.40	1.33	1.28									0.58
Apr. 4, p. m.		1.35	1.25	1.15	1.06								
Apr. 17, a. m.	1.38												2.74
Apr. 17, p. m.	1.34	1.28	1.22	1.18	1.12	1.03	0.94	0.86					
Means	1.43	1.36	1.28	1.21	1.12	1.03	0.94	0.86					1.61

TABLE 4.—*Atmospheric transmission for solar radiation*

Date	Solar altitude	Air mass		Intensity	Vapor pressure	Precipitable water	Atmospheric transmission		Difference
		m	$m\frac{P}{760}$	I			I/I_{R^2}	Computed	
1928	°			*Gr. cal. min. cm.*²	*Millimeters*	*Centimeters*			
Mar. 20	14.3	4.0	3.80	1.31	0.51	0.11	0.675	0.705	0.030
Do	19.3	3.0	2.85	1.39	0.51	0.11	0.716	0.752	0.036
Apr. 17	30.0	2.0	1.90	1.36	2.74	0.605	0.707	0.746	0.039
Sept. 6–7	30.0	2.0	1.90	1.31	4.57	1.00	0.693	0.721	0.028

In this table m is the value of the length of the path of the solar rays in passing through the atmosphere in terms of the length when the sun is in the zenith, as computed by Bemporad. In the following column m is multiplied by the ratio of the atmospheric pressure to standard pressure, or 760 mm. I is the measured intensity of solar radiation, and I_R^2 is the mean value of the solar constant, I_0 divided by the square of the earth's radius vector in terms of its mean value. The computed atmospheric transmission is obtained from the Monthly Weather Review, February, 1930, volume 58, page 52, Figure 1. The atmospheric depletion indicated by this computed transmission includes all that Fowle found correlated with pure dry air and water vapor. The difference between the two transmission values must be attributed to depletion by impurities in the atmosphere.

Comparing these differences with corresponding differences for Washington, D. C.; Madison, Wis.; Lincoln, Nebr.; and Davos, Switzerland, given on page 51 of the Review cited above, it is seen that the atmosphere at Mount Evans, Greenland, is relatively free from dust at all seasons of the year, as we would expect it to be.

RAIN-GAGE FUNNELS OF DIFFERENT DEPTHS

By John Glasspoole, M. Sc., Ph. D.

[Meteorological Office, London]

With reference to the article on "Rainfall catch as affected by different depths of funnels in the rain gage,"[1] it may be of interest to refer to some of the experiments which have resulted in the adoption of the deep-funnel gage as the standard pattern in the British Isles.

At the majority of the official stations of the Meteorological Office the 8-inch gage is used, in continuation of a practice which dates back to about 1870. According to the current specification the funnel has vertical walls 5¾ inches deep. By far the greater number of gages in use in the British Isles are, however, 5 inches in diameter. In the case of the standard "Snowdon" gage the diameter is 5 inches and the depth of the vertical walls is about 4 inches. In the Meteorological Office version of this gage the depth of the vertical walls is 4$\frac{11}{16}$ inches and the funnel proper slopes at 33½° to the horizontal. The rain is collected in a bottle holding about 3½ inches, standing in a copper can, the total capacity of which is about 9 inches. The inner can stands in an outer can, on to the top of which the funnel fits. The base of the outer can is splayed so that the gage can be fixed firmly in the ground at such a depth that the rim is exactly 1 foot above the surface. Somewhat similar gages, but of larger capacity are used for monthly measurements. In these gages a dip rod is used, but only for the purpose of giving a rough check reading. The actual measurement is made by pouring the water into a cylindrical glass measure graduated in inches and tenths. For daily observations, measuring glasses with taper bases are used. These glasses are subdivided to 0.01 inch or 0.1 mm., the former have an additional graduation at 0.005 inch for the purpose of making it easy to decide whether a small amount is to be counted as a "trace" or as 0.01 inch. This is important because in the latter case the day ranks as a rain day. These particulars are given in some detail because it is important, in this connection, to remember that the instruments used in the British Isles are very different from those used in America.

According to Mr. R. H. Scott, a former head of the Meteorological Office, the deep-funnel gage was invented by Quetelet. A gage with a vertical wall of 6.3 inches is described in "Sur le Climat de la Belgique, cinquieme partie" by Quetelet, published in 1852. The introduction of the deep-funnel gage in the British Isles was due mainly to Mr. G. J. Symons, the founder of the British Rainfall Organization, now incorporated in the Meteorological Office. It was first used about 1864, and subsequently on Mount Snowdon. It became known as the Snowdon pattern, and has gradually replaced gages of the British Association and Howard patterns, which have shallow funnels. Even at the present time, however, some 1,500 of the 5,000 voluntary observers in the British Isles use a gage of nonstandard pattern, of which the vertical walls above the funnel are usually less than half an inch in depth.

It must be admitted at the outset that in the normal conditions prevailing in the British Isles, the use of a deep-funnel gage makes no great difference to the measured annual total. It is not possible by a critical comparison of the monthly or annual records in a given locality to detect the returns from shallow-funnel gages. This generalization is supported by the records from stations which have gages of both patterns. Three typical cases are quoted below:

Station	County	Period of observation	Mean annual values			
			Shallow funnel	Suowdon funnel	Difference	
			Inches	*Inches*	*Inches*	*Per cent*
Tenterden	Kent	1876–1921	28.28	27.76	+0.52	+1.9
Swinton House	Berwick	1914–1921	26.16	26.03	+.13	+.5
Purley	Surrey	1907–1920	31.16	31.48	−.28	−.9

The differences year by year depart little from these mean values. It should be noted, however, that if any obvious error occurred—e. g., during snow—the same amounts were generally adopted for both gages. Some observers have noted that the shallow gage gave a slightly larger number of rain days.

It has been possible, however, to attribute inconsistencies in the *daily* readings at adjacent stations to the use of a shallow-funnel gage at one or more of them. During periods of snow and of intense rain or hail, the standard gage invariably retains a better sample of the precipitation. Although there is obviously more risk of loss with the shallow-funnel gage by outsplashing from the funnel during intense rain or hail few comparative readings are on record. Even when such readings are available some doubt often exists as to whether they are strictly comparable owing to such precipitation being particularly local.

Some of the earliest experiments in the British Isles on this subject were made by Colonel Ward, at Calne (Wiltshire) during the years 1865 to 1868.[2] Colonel Ward found that during the summer six months a shallow

[1] Monthly Weather Review, July, 1930, vol. 58, pp. 282–283.

[2] British Rainfall, 1874, pp. 25–34.

funnel gage (of copper) and a Snowdon funnel gage (of japanned iron) gave almost identical totals, while during the winter the former gave 0.136 inch more per month. The annual total was about 30 inches. During March and April the shallow-funnel gage gave on the average 0.027 inch more per month, during the five summer months 0.035 inch less, and during the remaining winter months as much as 0.150 inch less. Apart from the winter months, when the differences were due mainly to snow, the differences were very small. The relative increase in the catch of the Snowdon gage from the spring to the summer months is associated with the general increase in the intensity of the rainfall. The Snowdon gage had therefore marked advantages in winter and in summer. There was, however, a small defect due to the larger surface of the funnel which resulted in greater loss by evaporation. This was apparent only in March and April, when showers alternating with sunshine are a feature of the weather of the British Isles. Symons was satisfied that the advantages of the Snowdon gage far outweighed this small defect,[3] and this conclusion has been borne out by subsequent experience.

A series of comparative readings were subsequently made by Colonel Ward at Rossiniere, Switzerland, with two copper gages with the rims 1 foot, 6 inches above the ground and 9 inches apart. On 30 days during the period October, 1873, to February, 1875, the precipitation took the form of snow, which lay on the ground as soon as if fell. In each case the depth of snow was less than would fill the deep funnel. On these occasions independent estimates of the precipitation were made by inverting the funnel over undrifted snow and measuring in the ordinary way after melting. The comparative readings for these days were: Shallow-funnel gage, 2.67 inches; Snowdon funnel, 5.56 inches; and the independent methods, 5.43 inches.[4] It was concluded that good estimates of snowfall could be made by the use of the Snowdon funnel gage, and that serious losses resulted with the shallow-funnel gage.

Among the numerous experiments with different types of gages carried out in the British Isles, no other comparative readings appear to have been made with funnels of depths other than those already quoted.[5] Reference should, however, be made to the experiments recently carried out by Mr. A. J. Bamford in Ceylon, using deep-funnel and shallow-funnel gages.[6] These experiments were made with special reference to losses by evaporation and to the use of bottles in gages, and they confirm in general the results already given.

In the experiments made in the British Isles using funnels of different depths, the differences in the catch have not been correlated directly with the strength of the wind, as in America.[7] As a matter of fact some of the largest differences in the catch occurred with high wind, but in general there was little correlation between the differences and the strength of the winds. Possibly this is due to the gages in the British Isles generally being in a reasonably sheltered site, since the standard height of the rim of the gage is 1 foot above the ground.

[3] British Rainfall, 1874, pp. 39–40.
[4] See British Rainfall, 1874, face p. 29.
[5] A summary of the experiments made in the British Isles is given in the article on "The Development of Rainfall Measurement in the Last Forty Years," by Dr. H. R. Mill, British Rainfall, 1900, pp. 23–41, although curiously the question of the depth of the vertical funnel is not mentioned.
[6] The Meteorological Magazine, 1930, pp. 81–87.
[7] Monthly Weather Review, July 1930, vol. 58, pp. 282–283.

EARLY OPENING OF THE NEW YORK STATE BARGE CANAL

By J. H. Spencer

[Weather Bureau Office, Buffalo, N. Y.]

The New York State Barge Canal was officially opened this year on April 6, reported to be the earliest in 103 years. The steamer *William Hengerer* and three barges left Buffalo for New York with bonded wheat on the 7th.

There was practically no ice in Lake Erie after March 29. Navigation opened at Buffalo on April 3, with the arrival of the freighter *Coralia* from Detroit loaded with automobiles. The opening of navigation this year was 12 days earlier than the average.

These events reflect the mildness of the winter in this section of the country.

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910

Reviewed by Katherine B. Clarke

(Report on the scientific results of the *Michael Sars* North Atlantic deep-sea expedition, 1910. Edited by Sir John Murray and J. Hjort. Vol. I, Deposit Samples by J. Chumley, pp. 1–12; Physical Oceanography and Meteorology, by B. Helland-Hansen, text pp. 1–115, tables and plates pp. 1–102. Published by the Bergen Museum, Bergen, Norway, 1931.)

This volume is the first in a series on the scientific results of the *Michael Sars* expedition, a series which promises to be an exceedingly valuable contribution to the development of oceanography and associated sciences. Planned chiefly as a biological survey of the North Atlantic, a gratifying amount of geophysical and meterological data of real value was also obtained. Few persons are better qualified by knowledge and experience to write the discussion of these data than the eminent Norwegian oceanographer, Helland-Hansen.

The section on physical oceanography and meteorology has two major divisions, the text and the tables and plates. The text is further outlined in 10 chapters which cover the following topics: Introduction, sea surface and air, subsurface temperatures, salinities and densities (methods), local variations in general, short-period oscillations, the temperatures in the sea, salinities in the North Atlantic, stability, dynamics of the sea, and current measurements. The text is followed by an ample bibliography.

The chief interest from a meteorological viewpoint lies in the discussions of sea and air temperatures, the interaction of ocean and atmosphere, and diurnal, seasonal, and annual variations. Observations were made from June 3 to August 15, 1910. For purposes of statistical compilation these are divided into four series. On Deutsche Seewarte synoptic charts for each day of the cruise the position of the *Michael Sars* is shown. Accompanying graphs give for each day the meteorological conditions observed on the ship.

A very conspicuous positive correlation between surface temperatures and surface salinity was found. Regional variations were the chief cause for great variations in mean surface temperature. The daily period of surface temperature was not as evident as might be expected, but correlated closely with the amount of cloudiness, being more prominent with slight than with extensive cloudiness. A conclusion previously expressed by Helland-Hansen and Nansen, that variations in surface temperature are primarily the result of displacement of the surface

layers and that the warming and cooling effect of the air upon the sea is of secondary importance, has been substantiated by the results of this expedition. Mean air temperature was found to have a strong tendency to follow mean surface temperature. Only rarely was the difference between the two as much as 2° C. These differences though slight are of the utmost importance in atmospheric processes and necessitate the most careful observations of sea and air temperatures. The air was, as a rule, warmer than the sea by day and cooler by night, but 68 per cent of the averages give air temperatures lower than sea temperatures. Variations in humidity correspond closely to the variations in temperature differences between water and air. Moreover, variations in relative humidity coincide almost exactly with variations in absolute humidity.

In the study of gain and loss of heat the author reaches the same conclusions as Harvey;[1] namely, that evaporation is the chief cause for the loss of heat from the sea, excess of outward radiation, and direct convection to the air being of secondary importance; and that the stronger the heating of the surface layers the less the heating of the subsurface layers, due to greater stability and hence lessened convection to lower levels.

The study of seasonal variations was hampered by the fact that the author could find in literature only three cases where serial observations for deep offshore parts of the eastern North Atlantic have been taken at different seasons at the same geographical position. The author finds on the whole fairly good indication of "direct agreement between annual variations of the surface temperature toward the end of the winter and the temperatures for a considerable time (several months) afterward at 50 and 100 meters," p. 61.

Throughout the volume Helland-Hansen has amplified his discussion with results of his other observations, particularly those made in the North Atlantic in collaboration with F. Nansen. It is regrettable that the publication of results of such expeditions are so delayed. Such delays may only be compensated for by thorough and careful studies of results, such as are exhibited in this publication. The whole volume serves to emphasize the necessity for cooperation between investigators in physical oceanography and meteorology and for the collection of more detailed and accurate marine meteorological data.

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS OBTAINED DURING APRIL, 1931

By HERBERT H. KIMBALL

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, p. 41.

Table 1 shows that solar radiation intensities averaged below the normal intensities for April at all three stations. At Madison, Wis., on the 10th a high wind caused a dust storm of unusual density. The radiation intensity at normal incidence was reduced from 1.20 at 9:30 a. m., with air mass 1.5, to 0.141 at 2:07 p. m., with air mass 1.45. Skylight polarization, at 3:44 p. m., with the sun 30° above the horizon (m = 2.0) was less than 20 per cent, indicating that the depletion was due to reflection from rather coarse particles. The visibility, according to Weather Bureau officials at Madison, was only 3 miles.

Table 2 shows a deficiency in the total radiation received on a horizontal surface as compared with the normal amount for April at La Jolla and Fresno and an excess at all other stations for which normals have been computed.

Skylight polarization measurements obtained on 11 days at Madison, give a mean of 55 per cent and a maximum of 66 per cent on the 29th. At Washington, measurements obtained on four days give a mean of 59 per cent, with a maximum of 66 per cent on the 8th. These are slightly above the corresponding averages for Washington. At Madison, the values were slightly below the corresponding April averages for that station.

TABLE 1.—*Solar radiation intensities during April, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A. M.					Air mass P. M.				Local mean solar time
	c.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	c.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 8	3.45			1.05	1.13		1.00	0.85	0.68	0.58	4.17
Apr. 13	4.95		0.83	0.95	1.16	1.40	1.08	0.86			4.37
Apr. 14	5.79			0.73	0.85	1.07					6.50
Apr. 15	4.37			0.60	0.89	1.15	0.92	0.62	0.47		4.57
Apr. 16	6.76	0.47	0.60	0.76	0.97	1.27	0.49				4.17
Apr. 17	5.36		0.36	0.49	0.59	0.90					6.27
Apr. 20	7.04	0.62	0.75	0.88	1.00	1.39	1.01				4.17
Apr. 27	2.49	0.80	0.94	1.09							2.74
Apr. 28	3.45					1.32	1.02				3.30
Apr. 30	3.63		0.82	0.98	1.17	1.43					2.74
Means		0.63	0.72	0.84	0.97	1.21	0.92	0.78	(0.58)	(0.58)	
Departures		−0.07	−0.04	−0.05	−0.10	−0.11	−0.15	−0.11	−0.15	−0.04	

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during April, 1931*—Contd.

Madison, Wis.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A. M.					Air mass P. M.				Local mean solar time
	c.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 1	3.81					1.40	1.23				3.00
Apr. 4	3.30	0.54	0.66			1.39					2.87
Apr. 6	3.99				1.20	1.50	1.13				2.74
Apr. 7	3.30						0.98				4.75
Apr. 8	6.50				1.00	1.46	0.99				7.57
Apr. 10	4.95				1.13		[2] 0.26				3.15
Apr. 11	2.87		0.80	0.98	1.13	1.32					2.49
Apr. 17	5.16					1.32	1.03				4.17
Apr. 18	4.37			0.74	1.01	1.25					5.16
Apr. 24	2.62				1.06						2.49
Apr. 25	3.99			0.73	0.88						3.99
Apr. 27	2.74					1.43					2.87
Apr. 29	3.00				1.20	1.45					2.36
Apr. 30	3.15		0.76	0.87	1.06	1.35	1.01				3.30
Means		(0.54)	0.74	0.83	1.07	1.39	1.06				
Departures		−0.30	−0.18	−0.21	−0.13	−0.03	−0.13				

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Apr. 1	3.81		0.75	0.94	1.17	1.44					4.37
Apr. 5	3.15					1.44	1.20	1.03	0.90	0.75	3.45
Apr. 6	3.81		0.90	1.04							4.95
Apr. 7	5.36	0.75	0.81	0.96	1.13						8.18
Apr. 8	6.76			1.05	1.21	1.43					5.56
Apr. 10	4.17	0.40	0.53	0.69	0.86						3.99
Apr. 11	6.27		0.83	0.96	1.13	1.30					6.02
Apr. 22	3.15	0.64	0.73	0.85	1.07	1.27					3.30
Apr. 26	3.15	0.72	0.86	0.93	1.12						3.45
Apr. 27	3.63		0.72	0.94	1.10	1.38	1.11	0.93	0.75		3.15
Apr. 28	6.76		0.75	0.90	1.09						5.79
Means		0.63	0.76	0.93	1.10	1.38	(1.16)	(0.98)	(0.82)	(0.75)	
Departures		−0.09	−0.07	−0.05	−0.10	−0.06	−0.01	±0.00	−0.03	+0.03	

[2] Not included in means.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
	Average daily totals											
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2	248	461	400	373	241	472	263	562	524	400	442	379
Apr. 9	552	422	487	380	461	500	476	495	572	438	349	244
Apr. 16	503	332	468	251	463	556	409	621	623	402	454	388
Apr. 23	483	516	428	263	267	496	293	647	524	339	442	380
	Departures from weekly normals											
Apr. 2	−131	+73	−25	+81	−67	+72	−25	+36	−8	−22		
Apr. 9	+144	+20	+66	+64	+123	+57	+96	−44	+4	+3		
Apr. 16	+84	−64	+35	−55	+122	+78	+67	+49	+36	−30		
Apr. 23	+57	+82	−30	−60	−84	−28	−43	+29	−69	−80		
Accumulated departures on Apr. 29	+579	−2,121	−679	−588	+1,204	[1] +2,863	−514	+1,773	+238	−763		

[1] Records for February missing.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	h	m	°	°	°			
Apr. 1 (Mount Wilson)	12	50	−79.0	169.6	−2.0	138	------	------
			−22.0	226.6	+8.0	------	44	------
			+32.0	280.6	−9.0	149	------	------
			+58.0	306.6	+10.0	7	------	------
			+75.0	323.6	−17.0	------	126	464
Apr. 2 (Naval Observatory)	12	20	−63.0	172.7	0.0	46	------	------
			−5.0	230.7	+9.5	------	15	------
			+47.0	282.7	−8.0	77	------	138
Apr. 3 (Naval Observatory)	10	52	−50.5	172.8	−1.0	123	------	------
			+8.0	231.3	+8.0	3	------	------
			+7.5	230.8	−8.0	------	12	------
			+53.0	276.3	−4.0	9	------	------
			+59.5	282.8	−9.0	46	------	193
Apr. 4 (Mount Wilson)	9	45	−38.0	172.6	−2.0	------	125	------
			+17.0	227.6	+8.0	------	26	------
			+30.0	240.6	−7.0	------	8	------
			+67.0	277.6	−3.0	------	12	------
			+71.0	281.6	−7.0	26	------	197
Apr. 5 (Yerkes Observatory)	11	43	−62.2	134.2	+5.4	22	------	------
			−31.4	165.0	−2.9	9	------	------
			−23.1	173.3	−3.0	57	------	------
			+30.4	226.8	+6.3	------	36	------
			+32.5	228.9	+6.6	18	------	------
			+68.5	264.9	+5.7	31	------	173
Apr. 6 (Mount Wilson)	13	15	−51.0	131.4	+5.0	------	88	------
			−10.0	172.4	−2.0	------	92	------
			+40.0	222.4	+4.0	------	102	------
			+46.0	228.4	+9.0	5	------	287
Apr. 7 (Perkins Observatory)	10	45	−35.0	135.4	+10.0	------	217	------
			+3.0	173.4	+4.0	155	------	------
			+51.0	221.4	+7.0	------	186	558
Apr. 8 (Naval Observatory)	11	14	−70.0	87.1	+3.0	9	------	------
			−22.0	135.1	+5.0	------	216	------
			+13.0	170.1	−3.0	------	139	------
			+66.0	223.1	+2.0	------	123	487
Apr. 9 (Naval Observatory)	11	13	−70.0	73.9	+5.0	15	------	------
			−10.0	133.9	+4.5	------	170	------
			+28.0	171.9	−3.0	------	154	------
			+78.0	221.9	+3.0	------	46	385
Apr. 10 (Naval Observatory)	11	14	+3.0	133.7	+5.0	------	216	------
			+22.0	152.7	−3.5	------	31	------
			+41.0	171.7	−3.0	------	123	370
Apr. 11 (Perkins Observatory)	14	0	−60.0	56.0	+10.0	------	124	------
			+21.5	137.5	+12.0	------	124	------
			+56.0	172.0	+2.0	124	------	372
Apr. 12 (Naval Observatory)	11	12	−65.0	39.3	+22.0	------	77	------
			+21.0	125.3	+7.0	------	154	------
			+33.0	137.3	+3.5	------	31	------
			+69.0	173.3	−3.0	46	------	308
Apr. 13 (Naval Observatory)	11	15	−50.0	41.1	+22.0	------	46	------
			−37.5	53.6	+7.0	------	139	------
			+85.0	176.1	−3.0	31	------	216
Apr. 14 (Naval Observatory)	11	50	−61.0	16.5	+11.0	------	123	------
			−38.0	39.5	+22.0	31	------	------
			−22.5	55.0	+8.0	------	185	339
Apr. 15 (Naval Observatory)	11	17	−50.0	14.6	+10.0	------	216	------
			−27.0	37.6	+22.0	15	------	------
			−20.0	44.6	+11.5	15	------	------
			−11.0	53.6	+8.0	------	216	462
Apr. 16 (Naval Observatory)	11	28	−40.0	11.3	+11.0	------	154	------
			−15.0	36.3	+25.0	------	31	------
			+2.5	53.8	+9.0	------	123	308
Apr. 17 (Naval Observatory)	11	14	−23.5	14.8	+11.5	------	185	------
			−5.0	33.3	+2.5	------	46	------
			+16.5	54.8	+9.0	------	123	354
Apr. 18 (Naval Observatory)	11	14	−10.5	14.6	+11.0	------	123	------
			+30.0	55.1	+8.5	------	123	246

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	h	m	°	°	°			
Apr. 19 (Naval Observatory)	11	9	+2.0	13.9	+11.5	154	------	------
			+43.0	54.9	+9.0	123	------	277
Apr. 20 (Naval Observatory)	11	18	+16.0	14.6	+11.5	154	------	------
			+41.0	39.6	+10.0	31	------	------
			+58.0	56.6	+8.5	154	------	339
Apr. 21 (Naval Observatory)	11	0	+29.5	15.1	+12.0	------	123	------
			+57.0	42.6	+10.0	------	247	------
			+71.0	56.6	+9.0	------	62	432
Apr. 22 (Mount Wilson)	9	45	+42.0	15.0	+10.5	------	249	------
			+66.0	39.0	+8.5	------	295	------
			+89.5	62.5	+7.0	124	------	668
Apr. 23 (Naval Observatory)	11	13	−14.0	305.0	+15.0	------	62	------
			+55.0	14.0	+11.5	------	123	185
Apr. 24 (Naval Observatory)	11	27	−80.0	225.7	+8.0	15	------	------
			+0.1	305.8	+16.0	------	62	------
			+68.0	13.7	+10.0	93	------	170
Apr. 25 (Yerkes Observatory)	15	51	−59.6	230.4	+4.4	------	8	------
			+12.1	302.2	+14.1	16	------	------
			+14.0	304.1	+13.9	------	4	------
			+15.8	305.9	+14.3	8	------	------
			+16.9	307.0	+14.8	25	------	61
Apr. 26 (Naval Observatory)	14	20	−48.0	229.7	+4.0	15	------	------
			+27.5	305.2	+15.0	------	93	------
			+30.0	307.7	−7.0	9	------	117
Apr. 27 (Naval Observatory)	11	22	−38.0	228.1	+5.0	31	------	------
			+38.0	304.1	+17.5	------	62	93
Apr. 28 (Naval Observatory)	11	20	−23.0	229.9	+5.0	31	------	31
Apr. 29 (Naval Observatory)	11	24	−10.0	229.6	+5.0	15	------	------
			+33.0	272.6	+14.0	19	------	34
Apr. 30 (Naval Observatory)	11	22	+4.0	230.4	+5.0	15	------	------
			+48.0	274.4	+15.0	------	62	77
Mean daily area for April	------		------	------	------	------	------	278

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR APRIL, 1931 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

April, 1931	Relative numbers	April, 1931	Relative numbers	April, 1931	Relative numbers
1	d 34	11	d 36	21	Wc 38
2	32	12	36	22	41
3	29	13	a 44	23	27
4	------	14	38	24	Mc 29
5	Ec 25	15	37	25	37
6	31	16	a 31	26	21
7	a 40	17	41	27	19
8	44	18	22	28	14
9	45	19	a 20	29	Wc 17
10	a 29	20	20	30	18

Mean: 29 days=30.9.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. Samuels

Free-air temperatures during April were moderately above normal at the northern stations, viz, Ellendale and Royal Center, and below normal at the more southern stations. (Table 1.)

Relative-humidity departures were small and variable in most cases.

Vapor-pressure departures were mostly negative.

In Table 2 are shown the mean free-air temperatures and relative humidities at the Naval Air stations, and it will be noted that the agreement with the kite data is close when geographical location is considered.

Free-air resultant winds at the 3,000 meter level were predominantly westerly. The highest resultant velocities occurred in the northern and northeastern sections of the country.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	12.9	−2.7	13.8	−2.5	6.4	+0.8	14.2	−3.8	9.5	−0.9
500	12.0	−1.9	12.3	−1.9	6.4	+1.2	13.0	−2.7	8.7	+0.8
1,000	9.5	−2.0	9.7	−1.8	5.6	+2.9	11.1	−2.9	6.7	+1.2
1,500	6.9	−2.5	6.9	−1.8	2.5	+2.0	10.4	−2.4	3.7	+0.4
2,000	4.4	−2.7	4.3	−1.6	−0.6	+1.5	8.6	−2.1	1.1	+0.2
2,500	1.6	−2.6	1.3	−2.2	−4.0	+0.9	5.9	−2.2	−1.1	+0.6
3,000	−1.2	−2.3	−1.7	−2.5	−7.2	+0.7	3.1	−2.1	−3.1	+1.2
4,000	−7.5	−2.5	−7.7	−3.2	−13.6	+0.4	−2.1	−1.0	−7.7	+1.8
5,000	−11.7	−1.0			−20.8	−1.0			−12.7	+2.6

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow, Okla. Mean	Departure from normal	Due West, S. C. Mean	Departure from normal	Ellendale, N. Dak. Mean	Departure from normal	Groesbeck, Tex. Mean	Departure from normal	Royal Center, Ind. Mean	Departure from normal
Surface	73	+9	70	+7	63	−2	74	+1	66	+1
500	68	+5	66	+4	61	−3	66	−5	62	−3
1,000	62	+2	61	0	53	−7	60	−2	59	−3
1,500	60	+5	57	−3	53	−4	51	+2	62	+3
2,000	57	+7	51	−3	51	−4	48	+5	61	+4
2,500	54	+5	53	+1	50	−4	52	+11	59	+7
3,000	54	+6	53	+3	51	−3	40	0	55	+5
4,000	52	+7	68	+20	52	−4			46	−3
5,000	46	0			52	−2			51	+7

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1931*

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	11.16	−0.68	11.28	−0.58	5.73	−0.11	12.16	−3.28	7.81	−0.82
500	9.78	−0.62	9.60	−0.73	5.62	−0.06	10.17	−2.90	7.05	−0.31
1,000	7.65	−0.74	7.45	−1.14	4.62	+0.09	8.28	−1.86	5.94	−0.05
1,500	6.16	−0.51	5.74	−1.20	3.70	0.00	6.57	−0.58	4.95	+0.01
2,000	4.90	−0.20	4.47	−0.79	2.84	−0.13	5.43	+0.08	3.99	−0.01
2,500	3.69	−0.40	3.63	−0.30	2.13	−0.27	4.74	+0.48	3.19	+0.14
3,000	2.88	−0.39	2.98	−0.05	1.70	−0.23	2.80	−0.63	2.51	+0.10
4,000	1.53	−0.48	3.28	+1.28	0.93	−0.35			1.29	−0.34
5,000	0.73	−0.62			0.63	−0.15			0.75	−0.37

TABLE 2.—*Free-air obtained by airplanes at naval air stations during April, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)				Relative humidity (%)			
	Hampton Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	12.1	15.2	19.1	10.8	64	80	65	64
500	10.6	14.5	16.3	9.1	53	70	70	57
1,000	7.9	12.4	15.7	7.4	50	61	57	55
2,000	2.9	7.7	12.0	2.5	47	52	36	53
3,000	−3.0	2.2	5.6	−1.8	51	50	29	56
4,000		−4.8				65		

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during April, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Dallas, Tex. (154 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 87 E	0.7	S 66 E	0.6	S 8 W	1.4	N 75 W	3.6	N 50 W	0.5	S 28 E	0.9
500			S 27 E	6.1	S 42 W	3.2			N 65 W	2.9	S 14 E	3.7
1,000			S 4 E	4.8	S 76 W	4.0			N 55 W	5.4	S 44 E	2.0
1,500			S 10 E	2.6	N 52 W	5.3			N 64 W	6.3	S 26 E	0.5
2,000	S 31 W	1.8	S 3 E	2.2	N 45 W	5.4	N 76 W	5.7	N 69 W	8.7	N 45 W	0.1
2,500	S 82 W	2.7	S 75 W	1.7	N 49 W	8.0	N 68 W	8.5	N 59 W	10.2	N 28 W	1.5
3,000	N 85 W	5.3	N 86 W	2.6	N 44 W	7.8	N 60 W	7.6	N 66 W	6.8	S 65 W	1.2
4,000	N 83 W	7.1	N 61 W	10.1	N 78 W	6.5	N 70 W	9.0				
5,000	N 88 W	4.6					N 81 W	7.9				

Altitude (meters) m. s. l.	Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 21 W	0.4	N 75 W	1.7	S 87 W	1.4	N 37 W	0.6	N 55 E	1.4	N 50 E	0.7
500	N 74 W	2.2	N 86 W	1.9			S 8 W	0.3	S 87 E	3.7	S 75 E	1.7
1,000	N 75 W	3.2	S 79 W	3.6	S 72 W	4.3	S 33 W	1.0	S 53 E	2.9	N 38 E	1.0
1,500	N 67 W	3.8	N 83 W	4.2	S 86 W	6.2	S 82 W	1.0	N 89 E	1.4	N 27 E	0.5
2,000	N 72 W	3.3	N 77 W	5.7	N 88 W	5.9	N 77 W	4.0	N 42 W	0.5	N 70 W	1.0
2,500	N 79 W	5.5	N 68 W	6.5	N 90 W	5.6	N 80 W	4.5	N 85 W	2.2	N 71 W	3.0
3,000	N 60 W	6.4	N 60 W	8.9	N 80 W	4.9	N 85 W	4.7	S 89 W	3.2	N 60 W	3.2
4,000	N 61 W	9.0	N 61 W	10.7	N 59 W	4.1	N 88 W	7.8	N 80 W	6.3	N 51 W	7.7
5,000	N 55 W	9.8	N 76 W	12.5			N 79 W	10.2	S 76 W	4.8		

Altitude (meters) m. s. l.	Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	N 4 W	0.9	N 10 E	0.7	S 70 W	2.0	N 54 E	0.8	S 56 E	0.4	S 20 E	0.7
500	N 6 W	0.7	N 86 W	0.9			N 73 E	2.2	N 74 W	1.0	S 16 E	1.7
1,000	N 34 E	0.2	N 59 W	1.8			N 65 E	1.1	N 36 W	2.7	S 28 W	2.4
1,500	S 23 E	2.0	N 43 W	2.8			N 54 W	1.0	N 70 W	2.6	S 59 W	0.9
2,000	S 11 W	2.0	N 48 W	4.7	S 51 W	0.3	N 68 W	2.3	S 87 W	1.6	N 79 W	1.7
2,500	S 31 W	1.5	N 66 W	4.8	S 43 W	1.1	W	2.7	S 84 W	2.7	N 68 W	3.5
3,000	S 49 W	1.8	N 82 W	6.3	S 70 W	2.0	S 87 W	3.5	N 80 W	3.9	S 88 W	4.9
4,000	S 85 W	1.5			N 83 W	5.7	S 78 W	7.1	N 81 W	1.0	S 71 W	5.9
5,000					N 70 W	6.9	N 82 W	9.5				

Altitude (meters) m. s. l.	Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	S 85 E	0.6	S 83 E	2.5	S 42 E	2.6	N 18 E	0.5	S 52 E	0.9	N 64 W	0.5
500	S 29 W	0.8	S 77 E	2.3			S 41 W	0.9	S 2 W	2.6	N 87 W	7.1
1,000	S 82 W	3.7	S 19 W	1.0			N 82 W	4.5	S 8 E	3.1	N 68 W	4.1
1,500	S 88 W	5.2	S 58 W	2.1	S 23 E	2.7	N 64 W	6.6	S 5 W	2.3	N 63 W	7.5
2,000	N 84 W	4.9	S 39 W	2.5	S 36 W	2.2	N 57 W	7.9	S 40 W	1.8	N 67 W	7.3
2,500	N 56 W	5.5	S 36 W	2.6	S 70 W	2.7	N 56 W	8.0	S 72 W	3.9	N 65 W	8.5
3,000	N 45 W	4.7	S 53 W	3.4	S 89 W	3.9	N 47 W	8.4	S 85 W	5.7	N 62 W	9.8
4,000	N 80 W	4.9	S 83 W	3.8	N 79 W	5.6	N 48 W	8.7			N 57 W	11.4
5,000	N 68 W	9.5			N 79 W	8.8	N 52 W	8.2				

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during April, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	3,247	2,576	3,197	2,049	3,315
Maximum altitude (meters), m. s. l., reached	[1] 5,314	4,771	4,993	4,702	[1] 5,712
Number of flights made	32	31	30	20	31
Number of days on which flights were made	29	30	29	20	30

[1] Limited-height sounding balloon observation.

In addition to the above, there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. Bennett

GENERAL SUMMARY

During April the temperature in the northern and western sections of the country was above normal, while in the South from the Great Plains eastward to the Atlantic it was cool. The lowest temperature occurred during the early part of the month, and freezing weather was recorded in every State except Florida.

Precipitation for the month was below normal over much of the country. The greatest deficiencies occurred from the lower Mississippi Valley eastward, and in the western Lake region, the northern Great Plains and northern California, with some rather large areas receiving less than half the average for the month. On the other hand, precipitation much above the normal was noted in southern California and eastward to western Texas and New Mexico, some stations reporting the heaviest precipitation of record for April. Likewise the upper Ohio Valley, much of New York, Pennsylvania, the Virginias and Carolinas and the Florida Peninsula received more than normal.

TEMPERATURE

The general temperature situation in April was decidedly like that in March, each month averaging warmer than normal throughout northern and far western sections but cooler than normal elsewhere. However, different portions of April showed decided contrasts.

The opening week was generally colder than normal, but was warmer in the extreme Northeast, the upper Missouri Valley and the far West. Thereafter, for a fortnight, nearly all the country experienced warm weather, especially the north-central portion; but much of the Gulf section and part of the far Northwest were slightly cooler than normal.

The final decade of April was colder than normal in nearly all the country, particularly from the western Plains eastward to the Appalachian Mountains; but the Pacific States and much of the Plateau region and Florida averaged warmer than normal.

April averaged almost 5° colder than normal in Texas, where it was slightly colder than the coldest previous April in the 40-year period of State-wide record, and generally from central New Mexico and western Kansas eastward to the south Atlantic and southern middle Atlantic coast it was somewhat colder than normal. In the northern portion of the country and west of the Continental Divide, the month averaged warmer than normal, the greatest excesses, over 3° per day, being noted in Minnesota and California. At Los Angeles and Sacramento, Calif., it was the hottest April of record, and very nearly the hottest at Yuma, Ariz.

The highest temperatures were recorded usually during the period from the 8th to the 19th, but in the far Northwest and part of the south Atlantic area during the last five days of the month. A few stations in Arizona and California recorded temperatures above 100°, while in about half of the States the marks were 90° or higher. Most of the northern border, Ohio Valley, and Atlantic States recorded no marks quite as high as 90°.

The lowest temperatures occurred usually during the opening week, save in California, part of the Plains, and a few eastern States at various dates during the final decade. Florida, which recorded 33° at one station, was the only State entirely without freezing weather, but only in Michigan, Colorado, Wyoming, Montana, and Idaho, were marks below zero reached at any stations.

PRECIPITATION

The first week of April brought considerable rain to Washington and portions of the States adjoining, also in the eastern half to many portions of the Atlantic and East Gulf States and the upper and middle Ohio Valley. The second and third weeks were less rainy, viewing the country as a whole; but the far Northwest had moderate amounts till about the 18th, while from northern Arkansas to southern Minnesota most counties had considerable rain and the greater part of the Florida peninsula was visited by heavy downpours about the 15th.

From the 22d onward the rainfall was mainly more plentiful and more widely distributed, although the far Northwest and many north-central districts had either none or very little. Considerable portions of southern California and Arizona received heavy rains for the region and the time of year. The Rio Grande Valley and most of the middle Plateau and Rocky Mountain regions had much precipitation, likewise a broad area from Texas northeastward to and including the Appalachian region, the Ohio Valley, and the lower Lake region.

The month's precipitation was less than normal in about three-fourths of the States, yet there were many favorable features. The largest amounts, slightly over 10 inches, were reported from a few stations in Washington and Florida. Practically throughout the Ohio Valley, Virginia, Maryland, and New Jersey there was at least 1.5 inches at every station, and in a large part of the Ohio Valley and the vicinity of Lake Erie, the monthly precipitation was greater than normal for the first time in more than a year. Most of Virginia and of the central and western portions of the Carolinas had more rain than normal, and almost all of the Florida Peninsula a marked excess.

West of the Mississippi River there was more precipitation than normal in considerable portions of Arkansas, Oklahoma, and Kansas, almost throughout the drainage area of the Rio Grande, and in the southern portions of Arizona and California. At El Paso, Tex., 2.24 inches fell, more than eight times the normal April quantity, and 160 per cent of the greatest previous April fall in a record of more than 50 years. Los Angeles measured 3.02 inches, practically three times the normal, all of it within the space of six days, 22d to 27th, and almost three-fifths of it within 24 hours.

The inset on Chart V shows the departure from the normal for the month. As there shown the precipitation was considerably less than normal in the vicinity of the lower Mississippi River and in the upper Lake region and thence westward to northwestern Nebraska, the northeasternmost part of Wyoming, and the central portion of Washington. In the northern half of California the precipitation was decidedly deficient, save in the region of the Sierra Nevada Mountains.

SNOWFALL

The April snowfall was considerable over most portions of New York and eastern Ohio, in western and northern Pennsylvania, and the mountainous portions of Maryland, the Virginias, and North Carolina. On the other hand, the upper Lake region had comparatively little, and the greater part of the upper Mississippi and lower Missouri Valleys had either none whatever or too little to be measured.

In northwestern Kansas, the western half of Nebraska and much of South Dakota there was considerable snow, chiefly after the 20th of the month.

In the elevated portions of the regions near or to westward of the Continental Divide, the snowfall was mainly much below normal in the northern area and somewhat below in the southern. Certain districts in about latitudes 37° to 43° had considerable snowfall, especially the Sierra Nevada region.

SUNSHINE AND RELATIVE HUMIDITY

Rather abundant sunshine prevailed generally during the month in the northern and central areas from the Great Plains eastward to the Atlantic and in the Pacific regions from southern Washington to central California. On the other hand, the sunshine was deficient throughout much of Texas, Oklahoma, eastern Colorado, and New Mexico. Elsewhere it was generally near or slightly below the normal. The relative humidity was above the average from southern Arizona eastward to central Texas and Oklahoma. The plus departures were rather large in some of the areas, as would be expected from the large amount of precipitation received in those regions. Elsewhere the relative humidity was generally near or slightly below the normal.

SEVERE LOCAL STORMS, APRIL, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cattaraugus, Allegany, and Wyoming Counties, N. Y.	2					Snow	Trees, telephone and power lines considerably damaged.	Official, U. S. Weather Bureau.
Pittsburgh, Pa., and vicinity	3–4					Thunderstorm and heavy rain.	25 persons marooned on island; basements flooded; other property damage.	Do.
Havre, Mont., and vicinity	7–9					Wind	Minor damage to windows and signs; considerable loss by blowing soil.	Do.
Clark and Comanche Counties, Kans.	15	2–4 p. m.	9 mi.			Heavy hail	Character of damage not reported; path 19 miles long.	Do.
Edwards County, Kans	15	4 p. m.	5 mi.		$10,000	do	Character of damage not reported; path 10 miles long.	Do.
Pawnee County, Kans	15	P. m.				do	Damage heaviest near Rozel; character not reported.	Do.
White Signal, N. Mex	16	1–1:30 p. m.	1,760–3,520			do	Roofs considerably damaged; gardens destroyed.	Do.
Adair County, Iowa	18	4:30–5:30 p. m.			10,000	Wind, hail and probably a tornado.	Character of damage not reported	Do.
Dallas County, Iowa	18	P. m.	1,760		6,000	Hail	Buildings and crops damaged; path 3 miles long.	Do.
Lawrence, Monroe, Pike, and Wayne Counties, Miss.	19	P. m.				do	Considerable damage, character not reported.	Do.
Indianapolis, Ind. (7 miles south of).	20	A. m.				Thunderstorm	3 horses killed; truck and quantity of hay, feed, and other grains destroyed.	Do.
Washington and Oregon	21–23					Wind and dust	Severe injury to fruit blooms, vegetables, and truck; grains blown out; timber and communication lines prostrated.	Do.
Lynchburg, Va	22	12:15–12:30 p. m.	50		4,500	Tornado	Roofs blown from 24 houses; 1 small building demolished.	Do.
Utah (northern)	22–23					Wind and sand	Overhead wires and trees blown down; 11 freight cars blown from track; many residences damaged and several small buildings wrecked; crops injured; traffic delayed.	Do.
Palisade, Vineland, and Upper Orchard Mesa, Colo.	24	12.1 p. m.			12,000	Hail	Apricots considerably damaged; other fruits slightly injured.	Do.
Hosston to Gigsland, La	25	9 p. m.	2–6 mi.		10,000	Thundersquall, hail, and tornadic wind.	Buildings and crops damaged; much replanting required; path 55 miles.	Do.
Marietta to Kildare, Tex	25		3,520			Hail	Corn and fruit severely hurt	Do.
Belen, N. Mex	27	3:30 p. m.			2,000	do	Roofs, orchards, and gardens damaged	Do.
El Paso, Clint, and Sanderson, Tex.	28–29		1,760			Thunderstorm and hail.	Young crops destroyed; auto tops pierced; livestock killed; path 315 miles long.	Do.
Little Rock, Ark	30					Severe thunderstorm.	Small buildings floated from foundations; plate glass broken.	Do.

RIVERS AND FLOODS

By Montrose W. Hayes

There were more overflows in April, 1931, than in any other month since June, 1930, but those east of the Rocky Mountains were of minor importance.

Mild weather and rain near the middle of the month produced stages that were slightly above bankful in the Connecticut River, the Chenango (in New York) and the upper Susquehanna (in New York). There was no damage attendant upon the overflows. Some merchandise, valued at $25,000, in Hartford, Conn., was saved by being moved to a safe place before the overflow arrived.

Bankful stages were reached by some of the rivers in eastern North and South Carolina, western Alabama, northern Missouri, western Pennsylvania, and southeastern Ohio. The overflows were slight and the reported property damage was small, but three persons were drowned in Ohio.

Roads were damaged to an indeterminate extent by Pawnee Creek, in Pawnee County, Kans.

Floods in Oregon and Washington were of greater consequence than any of those east of the Rocky Moun-

tains, but information in regard to their extent and intensity is still incomplete. A discussion of them will appear in a later copy of the Review.

River stages that were unprecedentedly or unusually low for April prevailed in all of the Mississippi System, except in the Ohio Basin.

Table of flood stages in April, 1931

[All dates in April unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	Feet			Feet	
Connecticut: Hartford, Conn	16	12	16	17.9	13
Chenango: Sherburne, N. Y	8	10	11	8.8	11
Susquehanna: Oneonta, N. Y	12	11	13	14.5	11
Roanoke:					
Weldon, N. C	30	7	9	32.8	8
Scotland Neck, N. C	23	7	11	25.7	9
Williamston, N. C	7	5	18	8.6	13
Neuse:					
Neuse, N. C	15	8	9	15.8	9
Smithfield, N. C	14	7	11	15.8	9
Cape Fear: Elizabethtown, N. C	22	8	10	25.7	9
Peedee: Mars Bluff Bridge, S. C	17	10	11	17.4	11
Santee:					
Rimini, S. C	12	2	11	14.0	6
Ferguson, S. C	12	5	12	12.6	10
EAST GULF OF MEXICO DRAINAGE					
Tombigbee: Lock 10, Demopolis, Ala	39	6	10	42.3	8

Table of flood stages in April, 1931—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM					
Missouri Basin	Feet			Feet	
Grand: Chillicothe, Mo	18	21	22	21.9	21
Ohio Basin					
Kiskiminitas: Saltsburg, Pa	8	4	4	8.8	4
Allegheny: Lock 5, Freeport, Pa	24	4	4	24.7	4
Hocking: Athens, Ohio	17	5	5	17.4	5
Scioto: Larue, Ohio	11	4	4	11.1	4
Holston, North Fork: Mendota, Va	8	5	5	10.0	5
WEST GULF OF MEXICO DRAINAGE					
Trinity: Dallas, Tex	28	1	2	31.7	1
Rio Grande: Del Rio, Tex	10	29	29	10.1	29
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Willamette, Coast Fork: Saginaw, Oreg	9	1	1	10.4	1
Long Tom: Monroe, Oreg	8	Mar. 31	7	12.4	2
North Santiam: Mehama, Oreg	15	do	1	16.0	1
South Santiam: Waterloo, Oreg	20	do	1	21.0	1
Santiam: Jefferson, Oreg	10	do	2	17.5	1
Yamhill: McMinnville, Oreg	35	1	3	41.2	1
Willamette:					
Eugene, Oreg	12	1	1	13.0	1
Harrisburg, Oreg	10	Mar. 31	3	15.0	1
Albany, Oreg	20	2	3	22.9	3
Salem, Oreg	20	1	2	23.3	2
Oregon City, Oreg	12	1	5	15.0	3

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. Young

The weather over the North Atlantic during April was in marked contrast to that prevailing during the previous month, which was unusually stormy with abnormal pressure distribution. On the other hand, the number of days with gales during the current month was considerably below the normal, and the gales were not reported on more than three days in any 5° square, the maximum occurring in the square between the fortieth and forty-fifth parallels and thirtieth and thirty-fifth meridians. Up to time of writing only 21 vessels have rendered storm reports indicating a wind force of 9 or over; 4 vessels reported highest force 10, and 1 force 11.

Fog was unusually prevalent over the Grand Banks, where it was reported on from 8 to 14 days. The number of days in which it occurred in other localities is as follows: Along the American coast, between the thirty-fifth and forty-fifth parallels, from 6 to 8 days; over the steamer lanes, between the tenth and fortieth meridians, from 1 to 3 days; along the European coast, from 1 to 4 days; in the Gulf of Mexico, 4 days.

In the following table giving the barometric data at a number of island and coast stations, it will be noticed that Julianehaab, Greenland, and Cape Gracias a Dios, Nicaragua, are missing. From the former station reports were received on only 15 days, and from the latter, none since April 14. According to press reports the station at Cape Gracias was attacked and dismantled by Nicaraguan insurgents. Observations were resumed on May 19, however, and the results should appear in the table for June.

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, April, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Belle Isle, Newfoundland	29.87	[1] +0.04	30.40	21st	29.34	28th.
Halifax, Nova Scotia	29.97	[2] +0.04	30.40	13th	29.56	27th.
Nantucket	30.00	[2] +0.03	30.42	13th	29.46	2d.
Hatteras	30.06	[2] +0.03	30.40	13th	29.26	1st.
Key West	30.01	[2] −0.02	30.24	7th	29.80	1st.
New Orleans	30.09	[2] +0.05	30.30	6th [3]	29.84	1st.[3]
Turks Island	30.05	[1] +0.03	30.16	4th	29.96	16th.[3]
Bermuda	30.12	[2] +0.03	30.30	4th	29.84	24th.
Horta, Azores	30.21	[1] +0.10	30.44	16th	29.80	7th.
Lerwick, Shetland Islands	29.81	[1] +0.01	30.28	19th	29.34	5th.
Valencia, Ireland	29.96	[1] +0.07	30.48	13th	29.07	24th.
London	29.88	[1] +0.01	30.29	10th	29.12	25th.

[1] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date or dates.

Charts VIII and IX show the conditions on the 1st and 2d when there was a well-developed disturbance, central on the 1st near the Virginia Capes, the storm area that day extending south into the Gulf of Mexico.

On the 3d and 4th unusually strong northeast trade winds occurred in the vicinity of the Canal Zone, as shown by reports from the British steamship *Shirvan*, given in the table of gales. On the same date there was also a disturbance over the Azores, that reached its greatest intensity on the 4th. On the 6th and 7th a slight depression was off the American coast, between the thirtieth and fortieth parallels, and on the same date moderate gales were also reported from vessels in the middle section of the steamer lanes.

On the 8th and 9th the region between the twentieth meridian and the Azores was swept by a severe disturbance, and on the latter date the Italian steamship *Conte Biancamans*, encountered a northwest wind, force 11, as shown in table of gales.

From the 10th to the 21st moderate weather was the rule over the ocean as a whole, although on the 14th a stiff "Norther" was encountered in the Gulf of Mexico, as shown by the report from the American steamship *Alabama* in the table of gales, and on the 16th a LOW off the east coast of Newfoundland was responsible for winds of force 7 in the southerly quadrants.

On the 22d a LOW central near 35° N. and 53° W., drifted slowly northward during the next 48 hours, and moderate to strong gales occurred on the 22d in the northerly quadrants, and on the 23d and 24th in the southerly.

On the 23d a disturbance was central near 43° N. and 20° W., that increased in intensity as it moved eastward, and on the 24th northwest gales prevailed over the steamer lanes between the fifteenth and thirtieth meridians.

During the remainder of the month the weather conditions were hardly worthy of note, except that on the 27th a LOW central near Eastport, Me., was attended by moderate gales, the storm area extending as far south as the thirty-eighth parallel.

OCEAN GALES AND STORMS, APRIL, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Tatsuno Maru, Jap. S. S.	Tampa	Houston	27 48 N	84 44 W	Mar. 31	4 a. 1	Apr. 1	29.59	W	W, 8	W	W, 8	Steady.
Lotte Leonhardt, Ger. S. S.	New York	Aruba	28 21 N	73 57 W	do	7 a. 1	do	29.63	S	WSW, —	WSW	WSW, 9	S, WSW.
Persephone, Danzig M. S.	Las Piedras	Southampton	42 35 N	32 12 W	Apr. 2	11 p. 2	Apr. 4	29.92	SW	NNW, 8	NNE	N, 9	NNW, N.
Shirvan, Br. S. S.	Canal Zone	Lands End	12 12 N	76 32 W	Apr. 3	7 a. 3	Apr. 3	29.80	NE	N, —	ENE	—, 8	NE, ENE.
Prusa, Am. S. S.	Galveston	Barcelona	38 08 N	24 30 W	do	8 a. 4	Apr. 4	29.60	NNW	NNW, 9	NE	NNW, 9	NW, NE.
Stuyvesant, Du. S. S.	New York	Port au Prince.	33 46 N	74 02 W	Apr. 5	Mdt. 5	Apr. 6	29.82	WSW	SSW, 9	SW	SSW, 9	
President Wilson, Am. S. S.	Marseille	New York	40 50 N	31 50 W	Apr. 7	2 p. 7	Apr. 8	29.61	NW	NW, 5	NNW	NNW, 9	NW, NNW.
Jefferson Myers, Am. S. S.	London	Philadelphia	39 56 N	60 26 W	Apr. 8	2 p. 8	Apr. 9	29.36	SW	SW, 10	NNW	SW, 10	
Oilfield, Br. S. S.	Hull	Curacao	43 38 N	21 25 W	do	3 p. 8	do	29.30	NE	N, 10	N	N, 10	NE, NW.
Conte Bianeamano, Ital. S. S.	New York	Gibraltar	37 50 N	18 40 W	do	7 p. 9	do	29.42	NW	NW, 9	NE	NW, 11	NW, NNE.
Alabama, Am. S. S.	Port Arthur	Wilmington, N. C.	26 20 N	85 40 W	Apr. 13	2 p. 14	Apr. 14	29.76	ENE	NNE, 10	NE	NNE, 10	Steady.
Excelsior, Am. S. S.	Marseille	Boston	42 57 N	58 55 W	Apr. 15	2 a. 15	Apr. 16	29.88	N	N, 7	NW	NW, 9	
Examelia, Am. S. S.	Alexandria	do	43 40 N	42 50 W	do	Mdt. 15	Apr. 17	29.55	SE	SW, 8	SW	SE, 9	S, SW.
Boniface, Br. S. S.	Para	Antwerp	50 19 N	0 51 W	Apr. 17	11 a. 18	Apr. 18	29.45	WNW	N, 9	NE	NNW, 10	NNW, NE.
Bilderdijk, Du. S. S.	Rotterdam	Boston	42 21 N	45 10 W	Apr. 22	8 a. 22	Apr. 22	29.84	ESE	ESE, 9	S	ESE, 9	ESE, S.
Jamaica Settler, Br. S. S.	London	Kingston	47 00 N	14 30 W	Apr. 23	8 p. 23	Apr. 24	29.32	WSW	WSW, 7	NW	NW, 9	WSW, WNW.
Lord Kelvin, Br. S. S.	Halifax	Cable Grounds	50 10 N	23 10 W	Apr. 22	10 a. 24	Apr. 25	29.46	W	NW, 7	NW	NW, 9	Steady.
Express, Am. S. S.	Casa Blanca	New York	38 02 N	69 06 W	Apr. 26	9 p. 26	Apr. 27	29.61	S	SW, 9	WNW	SW, 9	S, WSW.
Cingalese Prince, Br. M. S.	Naples	Boston	42 24 N	65 49 W	do	7 a. 27	do	29.63	SE	SW, 6	W	WSW, 9	S, SW.
NORTH PACIFIC OCEAN													
Stuart Dollar, Am. S. S.	Legaspi	Los Angeles	35 20 N	159 00 E	Mar. 31	8 a. 2	Apr. 2	29.49	SSE	SW, 10	SW	SW, 10	SSE-SW.
Golden Peak, Am. S. S.	Shanghai	San Francisco	36 56 N	149 18 E	Apr. 2	10 a. 2	do	29.26	WNW	WNW, 10	W	WNW, 10	WNW-W.
Silvereedar, Br. M. V.	Balik Papan	do	38 16 N	154 58 W	do		do					NW, 9	
Nevada, Am. S. S.	Portland	Yokohama	46 25 N	155 32 E	do	10 p. 2	Apr. 3	28.96	NE	NE, 8	N	N, 11	NE-N.
Grays Harbor, Am. S. S.	Tacoma	do	48 05 N	157 03 E	do	6 a. 3	Apr. 4	28.69	E	N, 10	NNW	ENE, 10	
Do	do	do	40 32 N	148 06 E	Apr. 5	3 a. 6	Apr. 6	29.61	SE	SE, 9	SSW	ESE, 9	SE-WSW.
Canad. Winner, Br. S. S.	Victoria	Panama	14 28 N	95 58 W	do	3 p. 5	do	29.97	ESE	N, 10	N	N, 11	S-NxE.
Iowan, Am. S. S.	Los Angeles	Balboa	15 10 N	96 00 W	do	—5	do	29.88	ENE	ENE, 7	N	N, 10	ENE-N.
Golden Tide, Am. S. S.	Portland	Yokohama	49 08 N	142 20 W	Apr. 6	8 a. 6	Apr. 7	29.42	WNW	WSW, —	N	WNW, 9	WNW-WSW.
Grays Harbor, Am. S. S.	Tacoma	do	38 50 N	145 20 E	do	Noon 7	Apr. 8	29.13	WSW	W, 9	NW	W, 9	S-WNW.
Stuart Dollar, Am. S. S.	Legaspi	Los Angeles	40 55 N	161 40 W	Apr. 10	11 a. 10	Apr. 11	29.43	SW	SW, 7	WNW	WNW, 9	WSW-WNW.
Chief Capilano, Br. S. S.	Port Alberni	Osaka	49 25 N	174 15 E	Apr. 11	2 p. 12	Apr. 12	28.92	SSW	WSW, 9	WNW	WSW, 9	WSW-WNW.
Canad. Seigneur, Br. S. S.	Union Bay	Yokohama	48 11 N	168 22 E	Apr. 12	4 a. 12	do	29.04	W	W, 9	W	W, 9	W-WSW.
Golden River, Am. S. S.	Hong Kong	San Francisco	46 45 N	153 40 W	Apr. 17	4 p. 20	Apr. 20	29.93	NE	NE, 7	NE	NE, 9	NNE-NE.
Emp. of Russia, Can. S. S.	Victoria	Yokohama	49 32 N	170 59 E	do	4 p. 18	do	29.35	SSW	S, 8	W	S, 10	S-SSW.
Minnesotan, Am. S. S.	Los Angeles	Balboa	14 26 N	96 42 W	Apr. 22	—22	Apr. 23	29.82	ENE	ENE, 7	N	NNE, 9	ENE-NNE.
Golden Tide, Am. S. S.	Portland	Yokohama	43 30 N	156 26 E	do	3 a. 23	Apr. 24	29.55	SSW	SW, 7	N	SSW, 10	SSW-WNW.
Do	do	do	38 51 N	146 21 E	Apr. 25	9 p. 25	Apr. 26	29.87	NNW	NNW, 10	NNW	SSW, 10	SSW-NNW.
Jeff Davis, Am. M. V.	San Pedro	Honolulu	25 08 N	148 48 W	Apr. 27	4 p. 27	Apr. 27	29.67	SW	WSW, 8	W	WSW, 8	WSW-NW.
Pres. Madison, Am. S. S.	Seattle	Yokohama	47 50 N	165 03 E	Apr. 26	6 a. 27	do	29.12	SSW	S, 8	WSW	S, 8	S-WSW.
City of Los Angeles, Am. S. S.	Los Angeles	Honolulu	29 26 N	137 05 W	Apr. 28	3 a. 28	Apr. 28	29.60	SE	SE, 9	SE	SE, 10	Steady.
Shoyo Maru, Jap. S. S.	Yokohama	Los Angeles	41 19 N	159 19 E	do	1 p. 29	Apr. 30	29.36	SE	E, 9	NE	E, 9	
Golden Star, Am. S. S.	Hong Kong	San Francisco	41 05 N	153 55 E	do	8 p. 28	Apr. 29	29.43	SE	SE, 7	NE	NE, 9	SE-NE.
Do	do	do	43 10 N	159 35 E	Apr. 30	6 p. 30	May 1	29.03	SE	SE, 8	SW	SE, 9	SE-SW.
SOUTH PACIFIC OCEAN													
Canad. Conqueror, Can. S. S.	Panama	Auckland	32 55 S	174 20 W	Apr. 9	4 a. 10	Apr. 10	29.29	NNE	NE, 10	WSW	W, 10	

NORTH PACIFIC OCEAN

By Willis E. Hurd

Atmospheric pressure.—During the early half of April, 1931, low pressure was, for the most part, well developed in northern waters, with days of greatest intensity and lowest barometer in the Aleutian region on the 4th and during the 11th to 13th. For the same 15-day period the North Pacific anticyclone was well established in its usual position except during the first three or four days. On the 16th it spread northward, enveloping the Aleutian region and the Gulf of Alaska and giving barometric readings as high as, or higher than, 30.50 inches at Dutch Harbor and Kodiak on the 18th and 19th. Thereafter the anticyclone weakened and became disrupted in area, and toward the end of the month was displaced by cyclonic conditions over most of the eastern half of the ocean, except for a considerable strip along the American coast from lower Alaska southward, where the HIGH was reorganizing and, in lower latitudes, expanding westward. At Midway Island there were no pressure readings below 30 inches until the 28th.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, April, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.16	+0.07	30.90	30th	29.24	13th.
Dutch Harbor [1]	29.82	+0.02	30.54	18th	28.80	12th.
St Paul [1] [2]	29.79	0.00	30.52	26th [3]	28.86	12th.
Kodiak [1]	29.74	−0.01	30.70	19th	28.76	4th.
Midway Island [1]	30.16	+0.04	30.42	1st	29.58	30th.
Honolulu [4]	30.04	−0.02	30.20	10th	29.81	27th.
Juneau [4]	29.84	−0.12	30.75	21st	29.08	12th.
Tatoosh Island [4] [5]	30.04	0.00	30.42	20th	29.64	6th.
San Francisco [4] [5]	29.96	−0.08	30.21	8th	29.43	22d.
San Diego [4] [5]	29.93	−0.03	30.09	4th	29.71	2d.

[1] P. m. only in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] And on the 27th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—There was a considerable improvement in the weather conditions of April over those of March as regards storminess, especially west of the meridian of 180°, in which great area severe gales were much less frequent. Here, as in the preceding month, the roughest weather reported occurred to the westward of the one hundred and sixtieth meridian of east longitude. The severest cyclone of the month lay as a moderate LOW south of Japan on March 31. On April 1, with gathering energy, it lay east of Honshu, and on the 2d and 3d was southeast of the Kuril Islands, at which time it caused strong to whole gales over a large area in all quadrants, with a maximum reported wind force of 11 from the north on the 3d, encountered with snow by the American steamship *Nevada*, near 46° N., 155° E. This was the heaviest gale indicated as occurring along the trans-Pacific routes during the month. The storm moved rapidly east-northeastward and by the 4th, with abated energy, had become amalgamated with the Aleutian cyclone.

The second cyclone of some importance to shipping over the western part of the upper sailing routes was central over the Japan Sea on the 5th, and from this day until the 9th, during its eastward movement, caused fresh to strong gales, with heavy squalls of rain and snow, between Japan and about the meridian of 160° E.

No further days or periods of equivalent storminess occurred within this region, such later gales as were reported being more local and on only the 22d and 25th rising to whole gale force.

Along the upper routes between 170° east longitude and the American coast, gale winds were far less frequent and severe than to the westward, in spite of the frequently disturbed condition of the weather under the influence of the Aleutian cyclone. At most, winds of force 8 or over were reported on not more than two days in any one 5° square, and were usually of local character, on only one occasion attaining to force 10.

Along the California-Hawaiian routes gales were reported on only two days—the 27th and 28th; the former of fresh force; the latter of force 10, from the southeast, near 29° N., 137° W. The causative disturbance originated near the Hawaiian Islands about the 25th. It spread rapidly northward, joined with a depression lying off the California coast, and for the remainder of the month lay spread over a great part of the central and eastern region of the ocean. It had little violence except locally in its extreme southeast.

The only gales reported from the tropics were the northers encountered in the Gulf of Tehuantepec on the 5th to 7th, and on the 22d. The heaviest weather here occurred on the 6th, when winds of force 10 and 11 overspread for a few hours a considerable portion of the Gulf and to the southward for a distance of at least 250 miles below Salina Cruz. On the 22d a "Tehuantepecer" attained a force of 9. The high velocities in both instances were due to extensive anticyclones extending from the lower part of the United States over the Gulf of Mexico.

Winds at Honolulu.—The prevailing wind direction at Honolulu was from the east during April, with a maximum velocity of 26 miles from the same direction on the 4th. Toward the end of the month the winds changed to southwest and west with the existence of the far-spread cyclone to the northward.

Fog.—The change in fog occurrence from that of March was slight, the percentage of days on which it was reported being a trifle higher in some areas remote from land. Near the California coast, between about 35° and 40° N., it was observed on 11 days. Over scattered localities between 45° and 52° N., 130° to 155° W., it was noted on 10 days. Between 30° and 35° N., 145° and 167° E., it occurred on 9 days, similarly scattered. Between Hong Kong and Shanghai reporting vessels found it on three days.

Smoke.—As in March, smoke continued to be observed in April along the Central American and lower Mexican coasts, being actually reported by steamships on 10 days, and as due to brush and forest fires along the hills. It was noted on the 25th along the straits connecting Vancouver Island with the mainland.

Dust at sea.—Owing to the special interest of this occurrence, it is considered in connection with an account of the dust storm in Washington and Oregon April 21–24, 1931, which will appear in a subsequent issue.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By Giles Slocum

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for April of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the April, 1930, means from the 11-year means for April (1920–1930), and the changes from the temperatures for the preceding month of March, 1930.

The chart shows the number of observations taken during the month of April, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

During April, temperatures in both the Straits of Florida and the Caribbean Sea continue to possess distinctly cool-season values, the April 11-year means for both areas being intermediate between those for December and January. The trend is, however, distinctly upward, and the last quarter of April is approximately 1° warmer than the same quarter of March in the Caribbean Sea. In the Straits of Florida the temperature difference is nearly 2°.

The surface water was slightly cooler than the 11-year average during the first half of April, 1930 in the Straits of Florida. In the Caribbean Sea, the northwestern portion was somewhat cooler than the average, while the temperature departures were positive over the remainder of the sea with the exception of the eastern extremity, where available data give evidence of cooler water than in March. For the Caribbean as a whole, the departures were small throughout the month.

[1] In 3 cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

Table 1.—*Lengths of "Quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

Table 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for April (1919–1930)*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	43	79.1	14	75.9
1920	155	79.3	34	76.8
1921	179	78.4	46	76.9
1922	194	78.5	74	77.2
1923	389	78.8	109	77.6
1924	342	79.6	109	76.4
1925	251	79.6	101	76.5
1926	302	80.1	110	76.8
1927	313	80.0	128	77.2
1928	435	79.6	152	76.2
1929	495	79.4	126	78.0
1930	580	79.4	127	76.5
Mean (1920–1930)		79.3		76.9

[1] Not used in computations because of insufficient data.

Table 3.—*Mean sea-surface temperatures and number of observations, April, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding mouth	Number of obser-vatious	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	Apr. 1 to 7	125	79.3			33	75.5		
II	Apr. 8 to 15	146	79.1			36	76.1		
III	Apr. 16 to 22.	140	79.4			37	76.8		
IV	Apr. 23 to 30.	169	79.8			21	77.6		
Month		580	79.4	+0.1	+0.5	127	76.5	−0.4	+0.7

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1931

[For description of tables and charts, see January, 1931, Review, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	61.5	−2.1	Thomasville	90	17	Valley Head	29	1	3.42	−0.85	Troy (No. 1)	8.66	Tuskegee	1.44
Arizona	62.2	+2.3	2 stations	105	[1] 16	Alpine	14	9	1.09	+0.42	Wikieup	3.88	Goodyear	0.00
Arkansas	59.1	−2.4	Warren	92	18	Dutton	21	6	2.62	−2.43	Little Rock	6.43	Amity	0.62
California	58.6	+3.4	Greenland Ranch	106	22	Ellery Lake	7	25	1.28	−0.43	Squirrel Inn	7.87	Davis	T.
Colorado	44.7	+1.1	Las Animas	92	[1] 8	Dillon	−15	4	1.26	−0.62	North Lake	3.59	2 stations	0.14
Florida	67.5	−2.4	5 stations	90	27	Belle Glade	33	8	4.46	+1.74	Fort Pierce	11.16	Panama City	0.57
Georgia	61.9	−1.6	4 stations	89	[1] 26	Tallapoosa	27	7	3.01	−0.61	Clayton	7.00	Savannah	0.72
Idaho	45.7	+1.0	Lapwai	85	30	Felt	−1	3	0.95	−0.43	Kellogg	3.42	Dubois	0.04
Illinois	53.2	+0.9	Greenville	88	14	Mount Carroll	21	2	2.68	−0.78	Brookport	5.12	Paw Paw	1.41
Indiana	52.5	+0.6	Elliston	89	14	3 stations	21	[1] 2	3.13	−0.43	Boonville	6.04	Winona Lake	1.58
Iowa	50.9	+2.0	Estherville	92	8	Washta	17	1	2.29	−0.67	Bonaparte (near)	5.04	Lake Park (near)	0.82
Kansas	53.1	−1.0	2 stations	90	8	Goodland	20	21	2.41	−0.29	Claflin	4.04	Tribune	0.59
Kentucky	55.9	−0.1	do	89	[1] 16	2 stations	25	[1] 2	4.52	+0.49	Junction City	6.49	Hopkinsville	2.91
Louisiana	63.7	−3.4	Ruston	93	16	Dodson	31	6	2.25	−2.44	Minden	7.75	Lake Charles	0.38
Maryland-Delaware	51.4	−1.0	2 stations	84	9	Oakland, Md	18	30	3.08	−0.49	Oakland, Md	4.52	Coleman, Md	1.95
Michigan	44.4	+1.8	do	86	[1] 10	Deer Park (near)	−2	1	1.49	−1.06	Onaway (near)	4.33	Frankfort	0.17
Minnesota	45.8	+3.2	Beardsley	90	12	Grand Marais	9	5	0.86	−1.13	Grand Meadow	3.05	Crookston	0.05
Mississippi	62.6	−2.0	Eupora	93	15	Port Gibson	32	6	2.41	−2.43	Water Valley	5.70	Natchez	0.42
Missouri	54.8	−0.3	Caruthersville	90	17	Dean	22	5	3.07	−0.74	Downing	6.23	Jefferson City	1.38
Montana	43.9	+1.5	Glasgow	87	17	Adel	−6	3	0.56	−0.58	Red Lodge (near)	3.49	4 stations	T.
Nebraska	50.0	+1.0	2 stations	92	[1] 7	Mullen	10	25	1.38	−1.07	Hebron	4.55	2 stations	0.27
Nevada	50.7	+2.3	Logandale	98	[1] 18	Zorra Vista Ranch	6	3	0.72	−0.04	Lewers Ranch	2.87	Lovelock	0.00
New England	45.6	+1.9	2 stations	86	[1] 19	Garfield, Vt	11	12	2.90	−0.36	Rockport, Mass	5.13	Fort Kent, Me	1.06
New Jersey	49.8	+0.4	3 stations	80	[1] 18	Belleplain	20	30	2.85	−0.91	Woodcliff Lake	5.17	Phillipsburg	1.53
New Mexico	50.5	−0.6	San Marcial	92	19	Dulce	5	2	2.30	+1.32	Gallinas Planting Station.	7.22	San Marcial	0.26
New York	45.9	+1.6	2 stations	86	[1] 21	2 stations	13	6	3.32	+0.35	Boyds Corners	5.31	Chazy	1.02
North Carolina	56.2	−1.7	Newbern	88	9	Mount Mitchell	15	7	4.28	+0.76	Highlands	8.06	Southport	0.93
North Dakota	44.1	+2.5	Max	87	18	Hansboro	3	3	0.43	−0.96	Jamestown	2.38	Minot	0.00
Ohio	50.1	+0.4	2 stations	87	19	Holgate	21	7	4.31	+1.10	Portsmouth (1)	7.76	Montpelier	1.80
Oklahoma	56.7	−3.0	3 stations	88	[1] 14	2 stations	21	[1] 1	3.06	−0.72	Hollis	6.13	Atoka	1.06
Oregon	48.4	+1.6	2 stations	92	21	do	4	18	1.50	−0.47	Mehama	6.15	Frenchglen	0.11
Pennsylvania	48.4	−0.3	do	85	[1] 9	Ridgway	16	24	3.33	−0.11	Lycippus	5.93	Montrose	1.00
South Carolina	60.2	−2.1	Beaufort (near)	89	26	Caesar's Head	29	[1] 2	3.24	+0.16	Caesar's Head	6.93	Charleston	0.92
South Dakota	48.2	+2.5	Forestburg	97	12	Camp Crook	5	23	0.78	−1.32	Harveys Ranch	2.50	2 stations	T.
Tennessee	57.4	−1.3	Cedar Hill	90	16	Rugby	27	7	3.62	−0.86	McGhee	6.56	Memphis	1.27
Texas	61.4	−4.8	Fort McIntosh	97	26	Dalhart	18	1	2.36	−0.80	Boerne	7.09	Denison	0.12
Utah	48.4	+2.0	Leeds	90	19	Soldier Summit	8	3	1.00	−0.35	Silver Lake	3.85	Moab	0.02
Virginia	53.6	−1.0	Christ Church	90	10	Dale Enterprise	22	1	3.55	+0.23	Mendota	5.62	Quantico	2.03
Washington	48.8	+0.8	Wahluke	93	30	Paradise Inn	8	18	2.42	0.00	Forks	13.17	2 stations	0.00
West Virginia	50.7	−1.0	2 stations	88	[1] 14	Bayard	18	30	4.12	+0.48	Dam 19, Ohio River.	6.24	Davis	2.13
Wisconsin	46.0	+2.6	do	86	[1] 8	Long Lake	8	11	1.22	−1.36	Mondovi	2.35	Mellen	0.36
Wyoming	40.8	+1.1	Douglas	83	13	Dome Lake	−16	3	1.14	−0.35	Quaking Aspen Creek.	4.26	Eden	0.27
Alaska [March]	15.3	+0.4	Dillingham	60	3	Eagle	−44	14	1.25	−0.62	Ketchikan	11.58	Pilot Station	T.
Hawaii	69.9	−0.1	Pahala	100	27	Kanahuluhulu	42	[1] 9	8.79	−0.19	Puohakamoa (No. 2)	39.40	Waiopai Ranch	0.00
Porto Rico	76.6	+1.3	2 stations	95	17	Guineo Reservoir	51	7	7.25	+2.56	Rio Blanco	17.98	Potala	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							46.7	+2.7										70	2.81	−0.2										4.9		
Eastport	76	67	85	29.87	29.96	+0.03	41.8	+2.8	63	20	49	28	12	35	23	38	32	70	2.31	−0.5	11	7,591	s.	43	e.	1	8	5	17	6.9	1.0	0.0
Greenville, Me	1,070	6	----	28.78	29.96	------	40.7	------	77	20	52	20	12	30	48	----	----	----	2.42	------	12	5,483	nw.	27	------	13	9	7	14	----	9.5	----
Portland, Me	103	82	117	29.87	29.99	+.03	45.6	+2.6	65	19	54	30	12	38	26	39	31	61	3.23	−0.2	11	6,465	nw.	38	s.	26	15	6	9	4.5	4.4	0.0
Concord	289	70	79	29.67	29.98	−.01	46.2	+2.8	79	20	58	26	16	35	45	----	----	----	2.13	−0.6	9	4,796	nw.	28	w.	27	14	10	6	4.0	10.0	0.0
Burlington	403	11	48	29.54	29.98	−.01	45.7	+2.4	78	21	55	25	16	36	37	----	----	----	2.24	+0.1	12	7,019	n.	42	sw.	10	10	8	12	5.8	T.	0.0
Northfield	876	12	60	29.03	30.00	+.01	42.2	+1.9	79	21	54	20	16	30	47	39	36	79	2.27	0.0	10	5,225	s.	28	sw.	11	10	11	9	5.4	1.3	0.0
Boston	125	106	165	29.86	30.00	+.03	50.2	+3.8	78	20	59	32	12	42	30	42	33	57	3.12	−0.2	9	6,006	nw.	27	nw.	27	15	5	10	4.5	T.	0.0
Nantucket	12	14	90	29.98	29.99	+.02	47.0	+3.6	65	21	53	36	8	41	21	43	39	79	3.69	+0.7	11	11,822	sw.	49	ne.	7	15	7	8	4.6	0.0	0.0
Block Island	26	11	46	29.97	30.00	+.02	46.2	+2.2	63	18	52	34	8	40	21	43	40	82	2.48	−1.0	10	11,659	sw.	49	ne.	1	16	6	8	4.5	T.	0.0
Providence	160	215	251	29.82	30.00	+.02	49.7	+3.1	71	21	59	33	12	41	26	43	36	63	2.68	−0.5	10	8,565	nw.	48	nw.	27	15	7	8	4.3	T.	0.0
Hartford	159	122	----	29.83	30.01	+.02	49.6	+2.9	77	21	59	32	12	40	30	----	----	----	2.81	−0.6	11	------	s.	----	------	----	13	8	9	4.9	T.	0.0
New Haven	106	74	153	29.90	30.01	+.02	49.2	+2.0	71	20	58	32	12	41	28	44	40	73	3.98	+0.5	12	7,317	s.	34	ne.	1	13	9	8	4.5	0.0	0.0
Middle Atlantic States							51.5	+0.1										66	2.76	−0.3										5.2		
Albany	97	107	115	29.90	30.01	+.01	49.2	+2.4	80	21	59	31	12	40	37	41	32	57	2.31	−0.2	10	5,455	s.	30	se.	10	14	9	7	4.4	0.5	0.0
Binghamton	871	10	84	29.08	30.03	+.01	46.0	+0.6	78	20	56	26	5	36	42	----	----	----	3.72	+1.2	14	4,681	nw.	26	sw.	26	9	5	16	6.6	3.0	0.0
New York	314	414	454	29.68	30.02	+.02	50.4	+1.0	69	18	58	34	12	43	26	43	36	63	3.30	+0.1	10	11,600	n.	54	nw.	29	10	8	12	5.7	T.	0.0
Bellefonte	1,050	5	36	28.90	30.02	------	45.7	------	76	13	58	24	12	34	47	40	34	67	3.85	------	11	------	sw.	40	sw.	26	11	4	15	6.0	3.9	0.0
Harrisburg	374	94	104	29.64	30.04	+.02	50.9	0.0	76	21	60	35	30	41	31	44	36	61	2.01	−0.7	8	5,380	nw.	32	w.	26	11	8	11	5.0	T.	0.0
Philadelphia	114	123	367	29.91	30.04	+.03	53.2	+1.1	76	19	62	37	12	44	26	44	35	56	2.05	−1.0	8	10,666	sw.	46	ne.	1	11	8	11	5.0	0.0	0.0
Reading	325	81	98	29.67	30.03	------	51.2	+0.9	76	10	61	35	12	42	31	43	35	59	1.91	−1.4	10	5,202	se.	47	e.	1	11	10	9	5.2	0.0	0.0
Scranton	805	111	119	29.15	30.02	+.01	47.5	−0.6	77	20	58	28	12	37	40	41	31	63	2.30	−0.5	12	5,202	sw.	28	ne.	1	11	6	13	5.4	T.	0.0
Atlantic City	52	37	172	29.97	30.03	+.03	49.3	+1.5	67	18	55	37	12	43	24	44	39	72	2.12	−0.9	9	12,911	s.	62	ne.	1	13	7	10	4.4	0.0	0.0
Cape May	17	13	49	------	------	------	49.4	+1.0	69	18	57	33	30	42	25	46	44	85	2.23	−0.8	12	------	se.	----	------	----	12	7	11	----	0.0	0.0
Sandy Hook	22	10	55	29.98	30.00	------	49.6	------	70	18	56	37	12	43	24	44	38	70	2.38	−1.2	10	11,001	w.	50	ne.	1	12	8	10	4.7	0.0	0.0
Trenton	190	159	183	29.82	30.02	------	50.8	+1.0	76	21	61	33	12	41	31	44	38	67	2.07	−0.9	10	8,335	sw.	48	ne.	1	13	6	11	5.0	0.0	0.0
Baltimore	123	100	215	29.89	30.02	+.01	53.8	+0.2	75	17	62	36	7	45	28	46	38	60	2.77	−0.6	7	7,962	sw.	42	w.	26	11	9	10	4.9	T.	0.0
Washington	112	62	85	29.91	30.03	+.01	54.2	+0.9	82	10	64	35	7	44	37	45	36	57	2.87	−0.4	8	5,122	nw.	32	nw.	26	13	7	10	5.0	T.	0.0
Cape Henry	18	8	54	30.01	30.03	------	53.6	−1.0	82	26	61	37	13	46	36	48	45	76	3.49	+0.2	9	9,028	se.	42	ne.	6	13	6	11	4.8	0.0	0.0
Lynchburg	681	153	188	29.28	30.03	+.01	55.0	−2.3	84	14	66	33	3	44	40	48	42	64	3.11	+0.2	10	5,086	nw.	35	nw.	26	14	7	9	5.0	0.0	0.0
Norfolk	91	170	205	29.95	30.05	+.04	56.0	−0.8	82	14	66	36	7	46	36	48	42	68	3.24	0.0	8	9,321	s.	52	w.	26	13	6	11	4.9	0.0	0.0
Richmond	144	11	52	29.89	30.05	+.03	54.4	−2.2	84	14	66	35	8	43	39	49	45	76	3.97	+0.5	10	5,943	s.	36	sw.	22	13	4	13	5.1	0.0	0.0
Wytheville	2,304	49	55	27.65	30.04	+.01	50.8	−1.2	77	14	62	31	2	40	38	44	38	68	3.85	+0.9	14	4,206	w.	25	w.	29	10	8	12	5.6	9.3	0.0
South Atlantic States							60.5	−1.4										69	2.64	−0.4										5.2		
Asheville	2,253	89	104	27.71	30.08	+.05	53.4	−0.5	78	9	65	33	6	42	37	45	39	67	4.71	+1.7	11	5,678	nw.	28	n.	22	11	8	11	5.3	4.3	0.0
Charlotte	779	55	62	29.21	30.05	+.02	58.5	−1.3	82	9	68	37	7	49	31	50	43	64	2.60	−0.7	14	3,756	ne.	20	w.	26	11	3	16	5.8	0.0	0.0
Greensboro	886	6	56	29.10	30.06	------	54.5	------	81	14	66	32	8	43	41	48	43	70	4.28	------	14	5,894	sw.	28	w.	26	8	8	14	6.0	T.	0.0
Hatteras	11	5	50	30.03	30.04	+.03	58.0	−1.8	73	18	65	49	8	51	25	54	50	78	2.71	−0.8	9	8,742	sw.	42	nw.	22	15	6	9	4.9	0.0	0.0
Raleigh	376	103	146	29.64	30.05	+.02	57.4	−2.0	83	9	68	37	7	47	33	50	42	63	3.44	0.0	13	5,892	sw.	31	w.	26	10	7	13	6.0	0.0	0.0
Wilmington	78	81	91	30.00	30.08	+.05	60.6	−1.4	84	9	71	41	7	51	30	54	49	72	1.13	−1.5	8	5,095	sw.	24	sw.	4	12	12	6	4.5	0.0	0.0
Charleston	48	11	92	30.02	30.07	+.04	63.6	−0.9	84	30	71	43	7	56	26	57	53	74	0.92	−1.6	7	7,014	sw.	33	nw.	26	13	7	10	4.5	0.0	0.0
Columbia, S. C	351	41	57	29.68	30.06	+.03	60.8	−2.5	81	30	71	40	7	51	31	52	45	63	2.82	−0.1	11	4,733	e.	30	sw.	26	12	9	9	4.9	0.0	0.0
Due West	711	10	55	29.30	30.08	------	59.2	------	79	30	70	37	7	48	37	----	----	----	1.51	------	12	6,233	sw.	39	w.	26	12	2	16	5.5	0.0	0.0
Greenville, S. C	1,039	139	146	28.95	30.05	------	59.5	+0.9	78	29	69	38	7	50	32	50	42	60	3.63	−0.1	10	6,046	ne.	36	w.	26	11	6	13	5.3	0.0	0.0
Augusta	182	62	77	29.86	30.05	+.02	62.9	−1.3	83	3	74	40	7	52	35	55	51	72	2.92	−0.2	9	3,884	nw.	25	w.	4	12	8	10	4.9	0.0	0.0
Savannah	65	150	194	29.99	30.06	+.03	64.8	−1.2	86	30	74	42	7	55	28	56	52	72	0.72	−1.8	5	8,034	w.	36	w.	1	13	7	10	4.6	0.0	0.0
Jacksonville	43	209	245	30.02	30.07	+.03	65.8	−2.9	85	30	74	46	7	58	27	58	53	72	3.41	+1.0	6	7,552	n.	38	nw.	1	11	9	10	5.0	0.6	0.0
Florida Peninsula							71.3	−1.8										76	5.18	+3.0										5.7		
Key West	22	10	64	29.98	30.00	−.02	73.6	−2.1	84	25	79	59	7	68	17	68	65	77	3.73	+2.4	8	6,954	e.	48	w.	1	8	14	8	5.2	0.0	0.0
Miami	25	124	168	30.00	30.03	−.01	71.3	−1.5	82	27	77	48	7	66	22	66	62	74	4.59	+1.5	15	7,031	e.	30	w.	1	5	9	16	7.1	0.0	0.0
Tampa	35	79	197	30.01	30.05	−.01	69.0	−1.9	86	30	78	52	7	61	25	62	59	77	7.23	+5.2	7	7,794	e.	35	ne.	15	7	13	10	6.0	0.0	0.0
Titusville	44	5	----	30.01	30.06	------	68.9	------	87	26	77	46	7	61	29	----	----	----	2.40	------	4	------	e.	----	------	----	15	11	4	4.4	0.0	0.0
East Gulf States							62.8	−1.9										68	2.50	−1.7										4.9		
Atlanta	1,173	190	198	28.83	30.07	+.04	59.6	−1.4	82	17	69	38	2	50	27	50	42	59	1.83	−1.8	11	6,456	nw.	33	nw.	26	11	7	12	5.5	0.0	0.0
Macon	370	78	87	29.67	30.07	+.04	62.4	−1.5	84	30	74	40	2	51	37	53	46	62	2.02	−1.1	7	4,142	nw.	21	sw.	22	12	5	13	5.4	0.0	0.0
Thomasville	273	49	103	29.77	30.07	+.04	64.8	−1.9	86	30	75	43	7	54	31	56	50	67	1.31	−2.0	7	5,305	nw.	27	sw.	26	9	10	11	5.5	0.0	0.0
Apalachicola	36	11	51	30.03	30.07	------	64.7	------	80	26	72	47	6	58	21	59	55	74	1.17	−1.6	5	5,874	nw.	26	nw.	1	19	5	6	3.5	0.0	0.0
Pensacola	56	149	185	30.02	30.08	+.06	63.8	−2.9	80	16	69	44	1	58	19	58	53	74	1.80	−2.2	2	7,835	s.	35	nw.	1	13	10	7	4.8	0.0	0.0
Anniston	741	9	57	29.29	30.09	+.06	59.8	−0.6	85	17	72	33	7	47	39	----	----	----	2.69	−1.7	11	3,309	nw.	17	nw.	26	13	6	11	5.1	0.0	0.0
Birmingham	700	11	48	29.31	30.08	+.06	61.4	−1.9	86	17	73	36	1	50	33	52	46	65	4.39	−0.4	10	4,349	nw.	28	se.	19	13	9	8	4.8	0.0	0.0
Mobile	57	125	161	30.01	30.07	+.05	64.3	−2.0	85	18	73	45	6	56	27	58	55	80	3.21	−1.4	6	6,257	s.	30	nw.	21	14	7	9	4.4	0.0	0.0
Montgomery	223	100	112	29.83	30.08	+.05	63.4	−1.9	85	17	74	42	1	53	31	54	48	63	3.68	−0.6	10	4,324	s.	20	n.	5	13	6	11	5.0	0.0	0.0
Corinth	469	6	----	------	------	------	60.9	------	89	15	74	35	7	48	40	----	----	----	3.55	------	9	------	se.	----	------	----	11	13	6	----	0.0	0.0
Meridian	375	87	95	29.68	30.07	+.05	61.8	−2.2	87	17	73	38	7	50	36	53	47	65	3.86	−0.9	6	3,662	ne.	21	s.	2	12	11	7	4.7	0.0	0.0
Vicksburg	247	65	73	29.82	30.11	+.11	63.6	−2.0	86	16	74	40	22	53	30	55	50	68	0.67	−4.5	6	4,492	e.	22	s.	2	12	9	9	4.6	0.0	0.0
New Orleans	53	76	84	30.02	30.07	+.07	66.0	−2.8	85	18	74	43	1	58	28	59	54	72	3.39	−1.8	6	4,112	se.	18	ne.	22	13	6	11	5.0	0.0	0.0
West Gulf States							62.6	−3.9										72	3.00	−0.7										5.9		
Shreveport	249	77	93	29.80	30.07	+.10	63.2	−2.6	86	17	73	36	1	53	30	56	52	72	5.26	+0.6	10	3,873	se.	17	s.	2	9	9	12	5.8	0.0	0.0
Bentonville	1,303	11	44	28.69	30.07	+.11	54.8	−2.1	80	16	66	29	5	44	32	----	----	----	4.16	------	10	2,933	s.	18	n.	20	19	4	7	----	0.0	0.0
Fort Smith	457	79	94	29.58	30.06	+.10	59.0	−2.8	82	16	69	35	1	49	33	51	46	69	2.97	−1.0	10	4,792	e.	29	n.	20	13	6	11	4.9	0.0	0.0
Little Rock	357	136	153	29.69	30.07	+.09	60.6	−1.5	85	16	70	38	5	51	31	52	45	62	6.43	+1.2	10	5,203	n.	48	nw.	30	11	4	15	5.5	0.0	0.0
Austin	605	136	148	29.40	30.03	------	63.2	−4.6	87	2	74	39	5	52	37	56	51	71	5.03	+0.7	8	5,386	se.	29	w.	26	6	11	13	6.4	0.0	0.0
Brownsville	57	83	100	29.95	30.01	------	67.6	−6.1	92	3	75	49	6	60	24	62	59	81	0.57	−0.9	9	7,264	se.	31	se.	2	6	12	12	0.2	0.0	0.0
Corpus Christi	20	11	78	30.01	30.03	+.08	66.3	−4.5	79	25	72	48	5	60	28	61	58	81	1.20	−0.6	9	8,394	se.	31	s.	2	3	11	16	7.0	0.0	0.0
Dallas	512	220	227	29.50	30.05	------	61.0	------	84	25	71	37	5	52	31	----	----	----	1.50	−2.8	7	8,075	se.	40	nw.	20	10	11	9	4.7	0.0	0.0
Fort Worth	670	106	114	29.33	30.04	+.10	61.6	−3.4	88	25	72	38	1	52	31	54	48	65	1.97	−2.0	7	5,371	se.	34	e.	29	6	8	16	6.4	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.11	64.4	−4.3	80	17	69	44	1	60	17	60	57	81	2.26	−0.8	6	7,054	se.	29	n.	21	5	11	14	6.3	0.0	0.0
Groesbeek	461	11	56	29.57	30.06	------	61.0	------	82	2	71	36	1	51	34	----	----	----	3.39	−1.2	9	6,961	s.	31	n.	20	6	11	13	6.4	0.0	0.0
Houston	138	292	314	29.91	30.06	------	64.7	−4.6	84	17	73	42	1	57	26	----	----	----	4.54	+1.0	8	8,038	se.	35	n.	21	7	11	12	6.3	0.0	0.0
Palestine	510	64	72	29.51	30.08	+.12	62.0	−4.0	84	17	72	37	1	52	31	55	50	70	3.10	−1.3	11	4,899	s.	23	s.	2	10	9	11	5.3	0.0	0.0
Port Arthur	34	58	66	30.03	30.06	------	65.4	------	83	16	73	40	1	58	23	----	----	----	1.59	−1.4	0	5,129	s.	27	n.	21	10	9	11	5.4	0.0	0.0
San Antonio	693	242	301	29.30	30.02	+.09	64.2	−4.9	88	2	74	42	5	54	36	56	50	67	2.28	−0.9	13	7,501	e.	38	n.	3	5	17	8	5.7	0.0	0.0
Taylor	571	38	51	29.48	30.08	+.13	62.4	−5.1	85	25	74	37	22	51	40	----	----	----	2.91	−0.8	8	5,570	s.	26	s.	2	6	14	10	5.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Ohio Valley and Tennessee							54.7	−0.1										64	3.43	−0.2										5.2		
Chattanooga	762	190	215	29.25	30.06	+0.03	59.4	−0.9	86	17	70	36	2	49	32	50	42	57	2.53	−2.3	9	5,767	sw.	27	nw.	26	10	9	11	5.7	0.0	0.0
Knoxville	995	102	111	29.00	30.06	+.03	58.4	+0.4	84	17	69	38	1	48	33	49	43	63	4.81	+0.7	11	4,366	sw.	26	sw.	21	10	10	10	5.4	T.	0.0
Memphis	399	76	97	29.64	30.07	+.07	61.3	−0.5	87	16	71	39	1	52	27	52	44	60	1.29	−3.5	9	5,128	s.	26	s.	25	12	10	8	4.4	0.0	0.0
Nashville	546	168	191	29.50	30.09	+.08	58.4	−0.6	84	16	68	38	1	48	30	50	43	62	2.44	−1.7	9	5,921	nw.	28	nw.	1	13	7	10	4.9	0.0	0.0
Lexington	989	193	230	29.01	30.09	+.07	54.0	−0.3	81	19	63	30	2	45	28	----	----	----	4.36	+0.9	9	7,746	sw.	30	nw.	26	16	6	8	4.1	0.2	0.0
Louisville	525	188	234	29.50	30.06	+.05	56.0	−0.4	82	16	66	33	1	47	28	50	45	70	3.85	0.0	12	6,350	n.	33	w.	26	10	9	11	5.3	T.	0.0
Evansville	431	76	116	29.60	30.07	+.07	56.8	+0.1	83	16	66	36	1	48	26	50	44	68	3.10	−0.8	10	5,417	s.	26	sw.	9	10	8	12	5.2	0.0	0.0
Indianapolis	822	194	230	29.16	30.05	+.05	52.7	+0.6	80	16	62	30	2	44	32	44	37	59	3.58	0.0	13	6,513	nw	31	nw.	26	9	10	11	5.5	T.	0.0
Royal Center	736	11	55	29.25	30.06	------	49.6	------	79	13	61	26	2	38	36	----	----	----	2.55	−0.5	12	6,332	nw.	33	w.	28	10	9	11	5.7	T.	0.0
Terre Haute	575	96	129	29.44	30.06	------	54.7	------	83	16	65	30	2	45	32	47	41	66	2.68	−1.0	14	5,336	n.	25	n.	5	9	10	11	5.5	0.0	0.0
Cincinnati	627	11	51	29.38	30.06	+.05	53.4	+1.0	82	14	63	32	2	44	34	46	40	65	3.93	+0.8	10	4,597	sw.	26	nw.	26	12	8	10	5.0	1.8	0.0
Columbus	822	216	230	29.17	30.05	+.03	51.7	+0.5	81	14	62	31	7	42	34	44	36	62	4.38	+1.5	10	7,215	nw.	51	w.	26	14	4	12	4.8	T.	0.0
Dayton	899	137	173	29.09	30.05	------	52.4	+0.8	82	14	62	32	7	43	34	44	37	62	4.43	+1.2	10	5,539	ne.	27	nw.	26	13	8	9	5.1	T.	0.0
Elkins	1,947	59	67	28.06	30.08	+.05	47.5	−1.3	77	19	60	25	30	35	43	41	35	69	2.92	−0.7	11	4,026	nw.	28	w.	26	12	5	13	5.7	2.6	0.0
Parkersburg	637	77	82	29.41	30.07	+.04	53.1	−0.3	83	14	64	33	1	42	38	44	37	62	4.39	+1.2	11	3,802	nw.	30	nw.	26	14	4	12	5.1	1.0	0.0
Pittsburgh	842	353	410	29.12	30.04	+.02	50.6	−0.6	80	19	61	32	27	41	34	45	39	70	3.61	+0.7	9	6,867	w.	40	w.	26	12	5	13	5.5	2.7	0.0
Lower Lake Region							47.2	+1.8										64	2.79	+0.3										5.0		
Buffalo	767	247	280	29.16	30.00	−.01	45.2	+2.4	79	20	53	28	30	37	35	40	31	68	2.54	0.0	13	10,055	w.	60	w.	26	10	9	11	5.3	2.4	0.0
Canton	448	10	61	29.48	29.96	------	45.0	+2.5	82	21	56	24	12	34	35	----	----	----	2.42	+0.2	9	6,799	w.	40	w.	13	10	10	10	5.5	1.7	0.0
Ithaca	836	74	100	29.09	30.01	------	46.0	+1.0	78	21	56	26	12	36	40	40	33	65	2.48	0.0	12	7,055	nw.	34	s.	10	10	6	14	6.1	4.3	0.0
Oswego	335	71	85	29.63	30.00	−.01	45.2	+1.6	80	20	53	31	1	37	37	39	32	65	2.47	+0.1	14	7,181	w.	31	w.	27	9	8	13	5.9	T.	0.0
Rochester	523	86	102	29.44	30.03	+.02	47.0	+2.1	85	21	56	28	12	38	36	39	31	59	2.10	−0.2	12	6,072	w.	36	w.	28	12	7	11	5.3	T.	0.0
Syracuse	596	65	79	29.38	30.02	+.01	47.4	+3.0	82	21	56	29	12	38	36	----	----	----	3.07	+0.6	15	5,461	s.	27	sw.	26	12	6	12	5.5	1.0	0.0
Erie	714	130	166	29.25	30.03	+.01	46.6	+1.5	81	20	54	30	12	39	35	41	36	70	3.31	+0.6	11	8,640	w.	40	sw.	28	16	6	8	4.3	4.1	0.0
Cleveland	762	267	337	29.20	30.04	+.02	47.4	+1.2	81	9	55	32	2	40	34	41	34	62	3.46	+1.0	12	9,033	w.	49	w.	26	15	5	10	4.7	1.5	0.0
Sandusky	629	5	67	29.36	30.05	+.03	48.7	+1.5	82	20	57	33	28	40	37	----	----	----	4.14	+1.6	10	6,026	e.	34	w.	26	15	4	11	4.7	0.3	0.0
Toledo	628	208	243	29.36	30.05	+.04	49.0	+1.4	79	13	58	30	7	40	35	41	33	60	2.99	+0.3	10	8,246	w.	43	w.	28	18	4	8	3.9	0.3	0.0
Fort Wayne	856	100	119	29.12	30.05	------	50.0	+0.7	79	13	60	32	28	40	34	43	36	64	2.67	−0.4	12	6,146	nw.	34	nw.	26	16	6	8	4.6	2.1	0.0
Detroit	730	218	258	29.25	30.05	+.03	48.6	+2.4	80	13	59	29	6	38	37	41	34	64	1.87	−0.6	7	6,055	ne.	33	sw.	28	17	5	8	4.0	2.1	0.0
Upper Lake Region							43.6	+2.1										66	1.36	−1.1										5.2		
Alpena	609	13	92	29.36	30.03	+.01	40.7	+2.1	77	12	50	20	6	31	48	36	30	67	1.77	−0.5	8	7,823	nw.	36	nw.	26	11	10	9	4.8	2.6	0.0
Escanaba	612	54	60	29.37	30.05	+.03	39.7	+1.8	60	8	48	22	11	32	29	34	28	66	0.51	−1.7	7	6,701	s.	30	nw.	22	11	9	10	5.3	T.	0.0
Grand Haven	632	54	89	29.35	30.04	+.03	44.2	+0.5	72	15	52	24	6	36	31	38	32	66	1.08	−1.6	8	7,012	sw.	33	nw.	26	11	6	13	5.7	0.1	0.0
Grand Rapids	707	70	244	29.27	30.05	+.03	48.6	+1.6	79	9	59	27	6	38	40	40	31	56	1.75	−1.0	4	7,151	sw.	37	sw.	12	8	10	12	5.7	T.	0.0
Houghton	668	64	99	29.29	30.02	.00	40.2	+2.5	79	18	50	18	5	30	46	----	----	----	1.15	−1.1	8	6,293	e.	38	nw.	10	10	8	12	5.1	5.3	0.0
Lansing	878	6	88	29.08	30.03	------	47.1	+1.5	80	9	59	24	7	35	46	40	34	66	1.87	−0.7	8	5,934	nw.	32	nw.	26	15	2	13	4.9	T.	0.0
Ludington	637	60	66	29.33	30.04	------	42.6	+0.7	68	14	50	24	6	36	27	38	34	73	1.15	−1.4	8	6,683	n.	30	sw.	20	14	8	8	4.3	T.	0.0
Marquette	734	77	111	29.22	30.03	+.01	41.0	+3.2	80	12	50	22	11	33	47	35	29	65	2.08	−0.4	9	7,177	nw.	43	sw.	12	8	6	16	6.5	10.9	0.0
Port Huron	638	70	120	29.33	30.03	+.01	44.5	+1.5	79	13	54	27	7	35	39	38	33	70	2.28	0.0	8	7,231	n.	37	nw.	26	11	7	12	5.1	0.9	0.0
Sault Sainte Marie	614	11	52	29.33	30.04	+.01	38.5	+1.1	66	18	47	18	1	30	35	34	29	73	1.04	−1.2	8	5,943	nw.	31	nw.	28	14	7	9	4.3	2.7	0.0
Chicago	673	7	131	29.33	30.06	+.06	49.2	+2.3	80	13	58	32	2	41	36	42	35	65	1.75	−1.0	7	6,370	ne.	28	nw.	28	9	12	9	5.3	T.	0.0
Green Bay	617	109	141	29.36	30.02	+.01	45.4	+2.2	78	12	56	26	6	35	41	38	32	65	0.63	−2.0	6	7,405	s.	41	sw.	12	9	6	15	6.1	T.	0.0
Milwaukee	681	125	221	29.30	30.04	+.05	46.6	+2.8	78	12	55	30	23	38	41	39	32	64	0.90	−1.8	7	8,252	n.	37	sw.	12	11	10	9	5.1	T.	0.0
Duluth	1,133	5	47	28.81	30.05	+.04	42.0	+5.0	76	18	53	19	11	31	35	35	28	64	1.04	−1.0	7	7,989	ne.	38	w.	10	15	10	5	4.0	2.7	0.0
North Dakota							44.6	+3.8										54	0.54	−1.2										4.4		
Moorhead	940	50	58	29.00	30.03	+.04	44.6	+4.0	82	17	58	16	4	31	42	36	26	56	0.46	−1.7	5	6,927	n.	28	nw.	8	10	11	9	5.4	T.	0.0
Bismarck	1,674	8	57	28.22	30.02	+.05	45.6	+3.5	83	17	59	17	3	32	43	37	27	56	0.42	−1.1	4	6,299	nw.	35	s.	14	15	13	2	3.7	0.8	0.0
Devils Lake	1,478	11	44	28.42	30.02	+.03	42.4	+3.6	82	17	55	11	3	30	42	35	25	58	0.65	−0.9	5	7,282	n.	28	nw.	8	13	9	8	4.8	1.4	0.0
Ellendale	1,457	10	56	28.46	30.04	------	44.8	------	81	17	58	15	4	31	46	----	----	----	1.15	−1.0	6	9,895	nw.	48	nw.	8	9	15	6	5.0	1.7	0.0
Grand Forks	833	12	67	------	------	------	43.6	------	82	17	58	16	4	29	44	36	----	----	0.15	-----	2	------	nw.	37	w.	8	24	4	2	----	T.	0.0
Williston	1,878	41	48	28.02	30.02	+.06	46.0	+4.0	82	17	60	18	21	32	42	36	24	47	T.	−1.2	0	5,733	w.	36	nw.	8	15	13	2	3.1	T.	0.0
Upper Mississippi Valley							52.5	+2.3										63	2.08	−0.8										4.9		
Minneapolis	918	102	208	29.00	29.99	------	50.0	+3.6	83	8	60	28	26	40	34	----	----	----	1.20	−1.0	6	7,949	nw.	37	nw.	10	12	7	11	5.3	T.	0.0
St. Paul	837	114	149	29.12	30.04	+.05	49.6	+4.0	82	12	60	28	26	39	34	----	----	----	1.47	−0.9	7	6,916	n.	44	w.	10	16	5	9	4.6	0.2	0.0
La Crosse	714	11	48	29.25	30.03	+.05	50.2	+3.0	84	8	62	26	2	39	43	41	33	58	1.62	−0.8	9	3,284	nw.	25	sw.	12	13	6	11	4.9	0.3	0.0
Madison	974	70	78	28.98	30.05	+.06	48.0	+2.6	78	13	58	29	6	38	38	40	32	58	1.97	−0.8	7	5,385	nw.	30	sw.	12	13	6	11	4.7	T.	0.0
Wausau	1,247	4	62	28.69	30.04	------	45.7	------	78	12	58	23	2	34	41	----	----	----	0.66	−2.0	4	4,391	n.	24	w.	10	18	6	6	3.5	0.2	0.0
Charles City	1,015	10	51	28.97	30.06	+.08	50.0	+3.6	86	8	62	25	1	38	45	41	33	58	1.88	−0.6	8	4,437	nw.	28	sw.	12	16	9	5	3.8	0.0	0.0
Davenport	606	71	79	29.40	30.06	+.08	52.3	+2.4	86	8	62	30	1	42	34	44	36	60	2.71	0.0	9	5,924	w.	34	sw.	12	13	4	13	5.2	T.	0.0
Des Moines	861	5	99	29.15	30.06	+.09	52.2	+2.1	87	8	63	27	1	41	41	44	37	62	1.55	−1.4	9	6,243	nw.	35	s.	12	12	4	14	5.8	0.4	0.0
Dubuque	700	81	96	29.30	30.05	+.07	51.0	+2.4	84	8	61	27	2	41	36	42	34	59	1.43	−1.4	8	3,776	nw.	23	nw.	10	12	5	13	5.0	T.	0.0
Keokuk	614	64	78	29.41	30.08	+.10	53.2	+0.9	81	8	63	31	1	44	32	45	39	65	3.27	+0.3	11	4,345	n.	22	sw.	12	12	5	13	5.4	T.	0.0
Cairo	358	87	93	29.68	30.07	+.08	58.8	+0.7	85	16	68	38	22	50	28	51	46	70	4.00	+0.3	11	5,248	n.	27	nw.	21	10	6	14	5.9	0.0	0.0
Peoria	609	11	45	29.41	30.08	+.09	52.6	+1.7	84	8	63	27	6	42	36	45	39	68	2.23	−1.2	10	3,940	nw.	19	w.	28	15	7	8	4.0	T.	0.0
Springfield, Ill	636	5	191	29.38	30.06	+.08	54.9	+2.2	83	15	66	31	6	44	36	47	41	68	1.88	−1.6	10	7,214	nw.	29	nw.	26	8	14	8	5.3	T.	0.0
Hannibal	534	74	109	29.50	30.08	+.10	54.4	+1.0	81	8	64	33	1	45	36	----	----	----	2.18	−1.0	9	5,025	nw.	24	sw.	12	13	4	13	5.3	0.0	0.0
St. Louis	568	265	303	29.45	30.06	+.08	57.3	+1.5	84	15	67	35	1	48	36	48	41	62	3.23	−0.6	12	6,889	nw.	28	nw.	21	13	11	6	4.2	T.	0.0
Missouri Valley							52.4	+1.4										58	1.93	−0.9										4.7		
Columbia, Mo	784	6	84	29.23	30.07	+.09	54.7	−0.2	83	8	64	30	5	45	34	----	----	----	1.42	−2.4	6	4,708	w.	21	sw.	13	11	8	11	5.3	T.	0.0
Kansas City	963	161	181	29.04	30.08	+.12	55.3	+0.5	83	8	64	32	5	46	30	47	40	64	2.62	−0.5	11	5,842	s.	32	n.	20	13	6	11	5.1	T.	0.0
St. Joseph	967	11	49	29.02	30.07	------	54.2	−1.8	85	8	64	29	5	44	35	46	39	65	3.56	+0.5	9	5,173	sw.	25	nw.	20	15	6	9	4.7	T.	0.0
Springfield, Mo	1,324	98	104	28.67	30.09	+.12	54.2	+1.8	79	8	63	32	5	46	32	47	40	66	3.80	−0.1	9	5,814	s.	30	nw.	20	19	5	6	3.4	T.	0.0
Iola	984	11	50	29.01	30.07	+.12	54.4	−1.8	81	15	65	28	5	44	35	----	----	----	3.04	−0.4	11	3,754	s.	25	n.	20	12	7	11	5.4	0.0	0.0
Topeka	987	92	107	------	------	------	54.5	−0.2	86	7	65	29	5	44	38	----	----	----	2.49	−0.3	8	5,730	sw.	31	ne.	20	12	9	9	4.6	T.	0.0
Lincoln	1,189	11	81	28.78	30.06	+.12	53.0	+1.5	88	8	64	26	5	42	40	44	37	63	1.76	−0.8	9	6,429	s.	36	nw.	19	8	11	11	5.9	T.	0.0
Omaha	1,105	115	122	28.88	30.07	+.12	53.2	+2.0	88	8	64	27	4	42	39	43	34	57	1.22	−1.3	11	5,074	s.	29	n.	8	14	6	10	4.6	T.	0.0
Valentine	2,598	47	51	27.32	30.07	+.13	48.0	+2.3	88	12	62	21	4	34	44	38	27	55	0.67	−1.2	7	6,050	w.	32	nw.	8	9	14	7	4.8	1.9	0.0
Sioux City	1,135	94	164	28.83	30.05	+.10	51.8	+4.0	89	8	64	26	26	40	41	41	31	53	1.34	−1.4	5	7,984	nw.	41	nw.	8	10	9	11	5.3	T.	0.0
Huron	1,306	59	74	28.64	30.06	+.10	48.8	+3.7	89	12	63	22	3	35	52	39	28	52	1.06	−1.2	5	6,695	s.	35	nw.	8	15	12	3	3.5	0.9	0.0
Pierre	1,572	70	75	28.35	30.03	+.08	49.9	+3.1	85	11	64	24	4	36	43	39	27	48	0.40	−1.4	4	5,897	nw.	38	nw.	8	14	9	7	4.0	0.5	0.0
Yankton	1,233	49	57	28.74	30.07	+.12	51.4	+3.5	86	8	64	26	5	39	44	----	----	----	1.77	−1.0	7	5,006	nw.	32	nw.	8	12	11	7	4.6	0.1	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							44.7	+1.5										52	0.99	−0.6										5.4		
Billings	3,140	5	-----	-----	-----	-----	45.8	-----	74	30	61	14	3	30	44	-----	-----	-----	0.98	-----	4	-----	nw.	-----	-----	-----	12	8	10	-----	T.	0.0
Havre	2,505	11	67	27.38	30.01	+0.11	46.2	+2.5	81	30	60	16	3	32	42	36	23	50	0.68	−0.3	3	6,647	sw.	36	nw.	19	12	10	8	4.9	0.1	0.0
Helena	4,124	89	113	25.82	30.05	+.08	44.4	+0.9	71	17	57	14	23	32	36	34	21	45	0.25	−0.9	4	6,259	sw.	34	sw.	7	8	10	12	6.1	0.5	0.0
Kalispell	2,973	48	56	26.98	30.06	+.10	44.5	+0.9	76	30	56	21	23	33	38	36	26	55	0.25	−0.6	6	4,483	nw.	32	ne.	21	6	16	8	5.2	1.6	0.0
Miles City	2,371	48	55	27.50	30.08	+.12	48.4	+3.7	82	13	63	16	23	34	42	37	22	42	0.45	−0.7	3	4,694	s.	33	nw.	8	15	9	6	4.2	T.	0.0
Rapid City	3,259	50	58	26.64	30.08	+.13	47.2	+2.9	80	17	59	21	26	35	38	38	26	50	0.36	−1.7	3	5,050	w.	38	nw	8	11	11	8	4.8	0.1	0.0
Cheyenne	6,088	84	101	24.01	30.03	+.12	40.8	−0.1	70	12	52	14	3	29	37	33	23	55	1.72	−0.3	10	7,857	w.	50	nw.	1	7	8	15	6.5	5.6	0.0
Lander	5,372	60	68	24.65	30.03	+.09	43.6	+1.2	72	12	56	19	3	31	39	34	23	51	1.82	−0.2	10	4,080	sw.	36	sw.	13	11	10	9	5.2	15.3	0.0
Sheridan	3,790	10	47	26.12	30.05	-----	43.7	-----	78	17	58	14	4	29	47	35	25	56	2.15	+0.2	7	3,601	nw.	30	nw.	17	6	14	10	5.8	8.8	0.0
Yellowstone Park	6,241	11	48	-----	30.07	+.11	37.8	+0.8	62	12	49	12	3	27	31	-----	-----	53	0.95	−0.5	7	5,787	sw.	26	sw.	7	3	10	17	-----	3.3	0.0
North Platte	2,821	11	51	27.10	30.01	+.12	49.7	+1.1	84	11	62	23	25	37	42	40	31	61	1.25	−0.8	7	4,974	s.	27	nw.	8	9	10	11	5.5	6.5	0.0
Middle Slope							52.4	−1.0										62	2.81	+0.3										5.6		
Denver	5,292	106	113	24.73	30.01	+.11	47.5	+0.4	75	7	58	23	3	37	35	37	25	51	2.23	+0.2	11	4,998	s.	35	ne.	8	7	11	12	5.8	12.5	0.0
Pueblo	4,685	80	86	25.29	29.98	+.10	50.7	+0.6	81	7	65	23	4	37	47	39	26	48	1.02	−0.3	6	4,393	nw.	32	w.	1	9	12	9	5.6	1.8	0.0
Concordia	1,392	50	58	28.60	30.09	+.16	53.2	−0.3	86	8	64	27	5	43	42	46	40	69	3.38	+1.0	11	5,616	s.	25	n.	8	10	9	11	5.5	T.	0.0
Dodge City	2,509	11	51	27.46	30.08	+.18	51.6	−2.0	83	7	63	28	21	40	43	44	39	71	2.10	+0.2	12	8,555	s.	38	n.	8	12	7	11	5.1	T.	0.0
Wichita	1,358	139	158	28.62	30.06	+.13	54.2	−2.2	80	8	64	29	5	45	31	47	41	67	2.49	−0.4	11	7,592	s.	38	sw.	19	10	10	10	5.4	T.	0.0
Broken Arrow	765	11	56	29.25	30.08	-----	56.2	-----	79	7	66	31	5	46	32	-----	-----	-----	4.02	+0.3	10	7,616	se.	41	n.	20	12	5	13	5.5	0.0	0.0
Oklahoma City	1,214	10	47	28.78	30.07	+.15	57.2	−2.6	80	15	68	33	5	47	31	49	43	67	4.45	+1.2	10	5,902	s.	30	n.	20	10	7	13	6.0	0.0	0.0
Southern Slope							58.7	−4.1										62	2.74	+0.9										6.2		
Abilene	1,738	10	52	28.22	30.03	+.13	60.6	−3.8	90	2	72	32	5	49	39	50	43	61	2.15	−0.6	9	6,424	s.	31	n.	20	4	12	14	6.8	0.0	0.0
Amarillo	3,676	10	49	26.29	30.02	+.15	53.8	−2.0	81	7	66	32	21	42	39	44	37	63	1.57	−0.3	10	6,536	s.	26	n.	20	8	10	12	6.2	0.0	0.0
Del Rio	944	64	71	28.98	29.97	+.08	63.8	−6.8	89	25	74	39	5	54	40	56	50	68	2.68	+0.9	10	5,457	se.	33	n.	20	3	19	8	6.1	0.0	0.0
Roswell	3,566	75	85	26.37	29.96	+.11	56.7	−3.9	86	1	69	29	5	44	45	46	36	54	4.54	+3.6	10	5,662	s.	32	se.	8	9	13	8	5.6	0.0	0.0
Southern Plateau							60.4	+3.1										45	1.22	+0.8										3.8		
El Paso	3,778	152	175	26.16	29.91	+.08	62.6	−0.8	87	20	74	39	5	51	38	48	34	43	2.24	+2.0	9	7,621	e.	40	w.	2	16	11	3	3.6	0.0	0.0
Santa Fe	7,013	38	53	23.23	29.92	+.08	47.8	+1.1	70	19	59	27	4	36	31	37	26	51	1.98	+1.0	11	4,154	e.	25	nw.	2	9	9	12	5.6	0.1	0.0
Flagstaff	6,907	10	59	23.32	29.86	+.02	46.0	+3.8	72	20	61	18	9	31	46	37	-----	61	1.49	-----	8	5,413	sw.	30	w.	2	7	12	11	-----	T.	0.0
Phoenix	1,108	10	107	28.70	29.84	−.03	72.4	+5.4	96	20	86	52	9	59	37	54	39	35	0.40	0.0	2	3,757	e.	25	nw.	16	14	13	3	3.5	0.0	0.0
Yuma	141	9	54	29.70	29.84	−.05	73.6	+4.1	101	21	89	53	1	58	43	56	39	37	0.75	+0.6	2	3,035	sw.	25	s.	22	21	4	5	2.6	0.0	0.0
Independence	3,957	6	27	25.91	29.91	+.01	60.2	+5.1	86	19	74	33	24	46	39	43	-----	-----	0.74	+0.6	3	-----	nw.	22	w.	7	19	6	5	-----	0.0	0.0
Middle Plateau							50.7	+2.3										42	1.08	+0.1										4.5		
Reno	4,532	74	81	25.43	29.94	−.03	51.0	+3.7	82	21	66	25	3	36	46	39	27	47	1.35	+0.9	5	3,927	w.	32	w.	1	15	9	6	3.9	12.7	0.0
Tonopah	6,090	12	20	-----	-----	-----	51.2	-----	75	21	62	28	3	41	28	38	23	39	0.75	-----	6	-----	nw.	-----	-----	-----	-----	-----	-----	-----	-----	-----
Winnemucca	4,344	18	56	25.60	29.98	+.02	49.0	+2.3	77	21	66	21	3	32	49	36	20	38	0.32	−0.5	5	5,160	ne.	30	nw.	21	13	11	6	4.2	T.	0.0
Modena	5,473	10	43	24.57	29.89	+.01	48.4	+2.4	75	18	64	21	3	33	49	37	21	42	0.54	−0.4	4	7,710	w.	51	sw.	22	9	13	8	4.8	T.	0.0
Salt Lake City	4,360	163	203	25.60	29.96	+.04	51.7	+2.1	76	7	62	28	3	41	34	41	28	44	1.84	−0.2	8	5,831	nw.	55	e.	22	14	7	9	4.8	0.1	0.0
Grand Junction	4,602	60	68	25.34	29.90	+.02	53.6	+1.2	78	18	67	27	4	40	39	41	26	42	1.34	+0.5	5	4,365	se.	33	s.	22	10	11	9	5.0	T.	0.0
Northern Plateau							50.3	+0.6										50	0.57	−0.6										5.5		
Baker	3,471	48	53	26.47	30.08	+.08	45.0	−0.2	75	30	58	23	20	32	40	37	29	59	0.61	−0.5	6	4,269	se.	28	nw.	21	11	7	12	5.4	0.7	0.0
Boise	2,739	79	87	27.18	30.05	+.07	50.6	+0.2	76	30	63	29	3	38	36	41	29	48	0.78	−0.4	4	3,780	se.	26	nw.	7	7	8	15	6.0	T.	0.0
Lewiston	757	40	48	29.26	30.07	+.08	53.0	+0.1	84	27	65	31	3	41	39	-----	-----	-----	0.53	−0.6	6	2,665	e.	32	n.	28	10	11	9	5.4	0.0	0.0
Pocatello	4,477	60	68	25.47	30.00	+.06	47.4	+1.4	74	17	59	21	3	36	35	37	25	48	0.88	−0.6	8	5,738	se.	28	sw.	8	12	12	6	5.0	5.2	0.0
Spokane	1,929	101	110	28.01	30.07	+.08	49.3	+0.9	81	30	60	27	3	38	37	40	30	53	0.53	−0.6	8	4,393	sw.	30	ne.	22	9	7	14	6.1	T.	0.0
Walla Walla	991	57	65	28.97	30.05	+.04	53.9	+0.8	83	30	64	35	23	44	30	45	34	50	0.66	−0.8	6	3,666	sw.	24	ne.	22	12	10	8	4.8	0.0	0.0
Yakima	1,076	58	67	28.90	30.06	-----	53.2	+0.7	85	30	66	31	3	41	34	42	28	42	0.02	−0.4	2	4,088	nw.	33	ne.	22	8	13	9	5.7	0.0	0.0
North Pacific Coast Region							52.6	+3.6										66	2.58	−0.3										5.6		
North Head	211	11	56	29.85	30.08	+.03	51.2	+3.7	72	20	56	39	18	46	23	46	42	75	3.21	−0.9	14	9,200	s.	50	s.	6	13	9	8	4.8	0.0	0.0
Port Angeles	29	8	53	-----	30.07	-----	49.2	-----	74	23	57	33	19	41	31	-----	-----	-----	0.85	−0.6	8	4,261	s.	32	w.	16	9	11	10	-----	0.0	0.0
Seattle	125	215	250	29.93	30.06	+.03	52.6	+3.2	78	27	60	37	19	45	29	45	36	59	2.25	−0.1	10	6,049	s.	30	sw.	7	11	10	9	5.3	0.0	0.0
Tacoma	194	172	201	29.84	30.05	+.02	52.1	+3.4	77	27	60	34	19	44	32	-----	-----	-----	2.96	+0.1	10	6,033	s.	43	n.	21	9	12	9	5.3	0.0	0.0
Tatoosh Island	86	9	53	29.94	30.04	+.04	50.1	+4.0	75	23	55	40	1	45	24	47	45	83	6.33	+0.7	15	10,615	s.	45	s.	6	5	10	15	6.5	0.0	0.0
Medford	1,329	29	58	28.59	30.00	-----	54.7	-----	87	21	70	29	2	40	49	45	36	58	1.23	−0.1	6	-----	nw.	36	ne.	22	6	16	8	5.9	0.0	0.0
Portland, Oreg.	153	68	106	29.90	30.06	.00	55.6	+3.8	86	27	65	37	18	46	32	47	38	57	2.40	−0.5	10	4,301	nw.	32	ne.	22	7	10	13	6.0	0.0	0.0
Roseburg	510	75	99	29.49	30.04	−.03	54.2	+3.2	83	28	67	33	19	42	45	46	38	62	1.37	−0.9	10	2,869	n.	27	ne.	22	8	15	7	5.1	0.0	0.0
Middle Pacific Coast Region							59.8	+4.1										64	0.52	−1.3										4.1		
Eureka	62	73	89	29.98	30.05	−.06	52.2	+2.3	73	20	59	39	18	45	27	48	45	80	1.61	−1.7	7	4,156	n.	31	ne.	22	13	10	7	4.7	0.0	0.0
Red Bluff	330	5	58	29.58	29.94	−.09	64.6	+5.6	98	21	78	41	3	51	40	51	37	43	0.24	−1.5	3	4,353	nw.	29	n.	22	14	9	7	4.5	0.0	0.0
Sacramento	69	106	117	29.85	29.92	−.09	63.5	+5.4	96	21	77	39	3	50	39	54	46	61	0.05	−1.5	2	4,800	nw.	22	sw.	23	19	10	1	2.6	0.0	0.0
San Francisco	155	208	243	29.80	29.96	−.09	59.0	+4.0	84	20	67	48	10	51	31	51	46	71	0.31	−1.3	3	4,221	w.	25	w.	1	12	9	9	4.6	0.0	0.0
San Jose	141	12	110	29.82	29.97	-----	59.8	+3.1	92	20	74	38	2	46	42	-----	-----	-----	0.40	−0.7	2	3,992	nw.	33	sw.	22	13	9	8	4.0	0.0	0.0
South Pacific Coast Region							65.3	+6.0										62	1.75	+0.8										4.5		
Fresno	327	89	98	29.57	29.92	−.07	66.2	+6.0	96	21	80	44	3	52	38	52	40	47	0.86	−0.1	2	4,951	nw.	28	nw.	1	15	10	5	3.4	0.0	0.0
Los Angeles	338	159	191	29.57	29.94	−.05	66.0	+6.6	89	6	75	52	12	57	29	56	50	64	3.02	+2.0	5	3,127	sw.	17	ne.	26	13	8	9	4.9	0.0	0.0
San Diego	87	62	70	29.84	29.93	−.06	63.8	+5.3	79	6	70	53	4	58	21	58	54	76	1.38	+0.6	5	4,179	sw.	22	s.	26	9	11	10	5.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.87	29.96	-----	78.0	+1.4	89	16	83	70	14	73	17	-----	-----	-----	8.29	+3.9	17	7,810	e.	30	ne.	12	1	20	9	6.5	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	-----	[1]29.81	−.01	83.6	+2.0	95	3	91	73	20	76	19	-----	-----	[1]76	1.45	−1.4	8	6,592	nw.	25	nw.	30	1	21	8	6.7	0.0	0.0
Cristobal	36	6	97	-----	[1]29.84	−.02	83.2	+1.4	89	30	87	75	18	79	12	77	75	[1]78	4.30	0.0	21	9,013	n.	25	nw.	23	1	21	8	6.4	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]29.37	[2]29.91	-----	26.1	-----	57	22	36	−8	2	16	38	22	14	58	0.11	-----	2	3,054	n.	24	ne.	30	9	4	17	6.5	T.	0.0
Juneau	80	11	50	[2]29.75	[2]29.84	-----	43.2	-----	67	21	49	31	1	37	27	39	34	74	7.44	-----	19	4,459	s.	27	se.	5	7	4	19	6.8	5.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.00	[2]30.04	-----	72.4	−0.6	80	18	77	65	20	68	11	65	62	70	0.69	−1.4	15	6,999	e.	26	e.	4	10	16	4	4.3	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

Table 2.—*Data furnished by the Canadian Meteorological Service, April, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				38.0		45.3	30.7	56	18	6.08		0.0
Sydney, C. B. I	48	29.91	29.96	+0.07	40.8	+5.8	48.2	33.4	59	22	3.62	−0.23	7.0
Halifax, N. S	88	29.85	29.96	.00	43.6	+5.8	51.7	35.5	66	27	3.63	−0.55	T.
Yarmouth, N. S	65	29.85	29.92	−.04	42.6	+3.7	49.1	36.2	63	29	3.82	0.00	T.
Charlottetown, P. E. I	38	29.85	29.89	−.01	40.0	+4.8	47.0	33.0	58	26	1.88	−0.77	7.6
Chatham, N. B	28	29.82	29.85	−.05	40.3	+4.8	50.5	30.1	67	20	2.24	−0.39	2.7
Father Point, Que	20	29.87	29.89	−.04	38.2	+5.0	45.0	31.5	58	24	0.42	−1.16	0.6
Quebec, Que	296	29.63	29.96	−.03	42.2	+7.1	51.2	33.3	74	23	2.67	+0.58	2.2
Doucet, Que	1,236				33.9		45.9	21.9	75	−10	1.36		1.9
Montreal, Que	187	29.73	29.94	−.06	46.5	+6.8	55.6	37.3	79	26	2.82	+0.58	T.
Ottawa, Ont	236	29.70	29.96	−.06	45.8	+5.8	57.1	34.6	82	24	2.39	+0.89	1.9
Kingston, Ont	285												
Toronto, Ont	379	29.60	30.02	.00	44.8	+4.0	53.5	36.1	78	28	1.90	−0.47	2.2
Cochrane, Ont	930				34.0		44.1	23.9	68	4	3.57		16.2
White River, Ont	1,244												
London, Ont	808												
Southampton, Ont	656	29.29	30.02	−.01	41.1	+2.4	50.3	31.9	72	22	1.91	+0.11	1.0
Parry Sound, Ont	688	29.31	30.01	−.01	40.3	+2.7	49.0	31.7	75	23	2.38	+0.47	3.6
Port Arthur, Ont	644	29.29	30.00	−.03	38.4	+4.9	47.4	29.4	65	18	0.77	−0.95	6.2
Winnipeg, Man	760	29.18	30.03	+.01	41.7	+5.8	52.4	31.0	75	11	0.34	−0.71	1.4
Minnedosa, Man	1,690	28.17	30.02	+.01	40.3	+4.3	54.2	26.4	81	6	0.15	−0.91	1.2
Le Pas, Man	860				36.6		48.7	24.5	73	−7	0.20		0.3
Qu'Appelle, Sask	2,115	27.70	29.96	−.03	42.2	+4.8	55.9	28.4	80	8	T.	−1.05	T.
Moose Jaw, Sask	1,759				44.6		60.0	29.1	80	12	0.02		0.2
Swift Current, Sask	2,392	27.41	29.95	−.01	44.0	+2.7	59.1	28.8	77	9	0.24	−0.69	1.6
Medicine Hat, Alb	2,144												
Calgary, Alb	3,428												
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.41	30.00	+.02	41.2	+5.1	53.8	28.7	77	9	0.28	−0.55	0.3
Battleford, Sask	1,592												
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.79	30.05	+.04	51.3	+4.5	58.3	44.4	75	38	1.11	−1.26	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

Late Reports, March, 1931

Medicine Hat, Alb	2,144	27.54	29.84	−.16	31.3	+3.8	42.2	20.4	67	−9	0.52	−0.24	4.6
Banff, Alb	4,521	25.32	30.02	+.08	26.7	+6.5	36.5	16.9	50	−11	0.80	−0.61	7.4
Edmonton, Alb	2,150	27.73	30.10	+.14	20.6	−3.6	28.9	12.3	53	−26	1.25	+0.53	12.4

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TWO SERIES OF ABNORMAL WINTERS

By Thomas Arthur Blair

[Weather Bureau, Lincoln, Nebr., March 11, 1931]

In the middle Missouri Valley and adjacent portions of the Great Plains and of the Mississippi Valley, there was a remarkable series of six consecutive cold winters (December to February, inclusive), from that of 1882–83 to that of 1887–88. In the same region a series of six consecutive warm winters occurred from 1918–19 to 1923–24, inclusive. These persistent tendencies of six years' duration are clearly shown in Figure 1, in which are plotted the accumulated sums of departures of the winter temperatures, for the States of Nebraska and Kansas and for the cities of Des Moines and Huron.

The continuance of such abnormalities through successive winters suggests the persistence of important pressure anomalies. If the average pressure deviations of the six cold winters be entered on one chart, and those of the six warm winters on another, the "accidental" variations of the individual years will be largely eliminated, and the resulting maps should show some of the larger characteristics common to the winters of either series, and perhaps give some additional information about the nature of those pressure oscillations and correlations with which Hildebrandsson, the Lockyers, Walker, and others have dealt so extensively. In Figures 2–9 an attempt has been made to draw such charts for the entire globe and for departures of temperature and precipitation as well as those of pressure. The data were taken from World Weather Records (1). It is recognized that they are very inadequate in many parts of the world, especially for the years after 1920. Many irregularities of the curves are doubtless thus omitted and some large areas perhaps improperly represented, but the main features of the various distributions, especially in the Northern Hemisphere, are unmistakably shown.

Winter-pressure deviations.—Figure 2 shows the departures from normal pressure for the months of December, January, and February for the period of six years, beginning with December, 1882, and ending with February, 1888, here called the cold winters of 1883–1888, and Figure 3 similarly for the warm winters of 1919–1924. A general reversal of pressure departures in roughly latitudinal belts is the most evident feature of these charts. The reversal is practically complete in the Northern Hemisphere but doubtful in the Southern Hemisphere. In the cold winters, a band of subnormal pressure surrounding the globe and centering at about the Tropic of Cancer but with extensions into the southern oceans, separates belts of above normal pressure in higher latitudes, both north and south. In the warm winters the central belt is one of high pressure in about the same latitude with southward extensions over the oceans and there is a complete north polar belt of low pressure. The southern belt of low pressure appears to be incomplete, accepting the positive departure at the South Orkneys, based on a short record, as representative of Antarctic regions.

The charts show a weakening of the tropical high-pressure belt in the Northern Hemisphere in the cold winters, and a strengthening in the warm winters, with corresponding increases and decreases, respectively, of pressure in north polar regions. The well-known contrast between Iceland and the Azores is strongly shown in Figure 3, but is weak in Figure 2. On the other hand

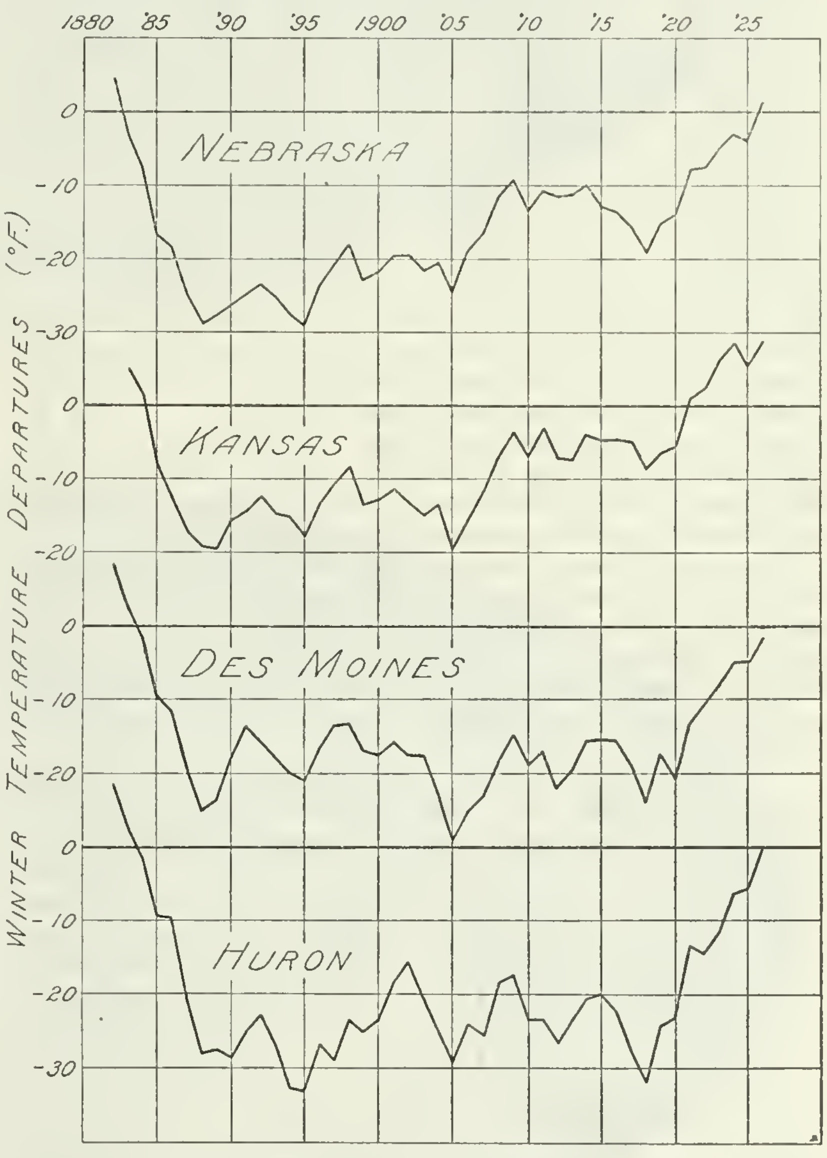

Figure 1.—Accumulated sums of departures of winter temperature for Kansas and Nebraska and Des Moines, Iowa, and Huron, S. Dak.

the opposition between Honolulu and Alaska is well developed in the cold winters but not in the warm winters. The departures at Honolulu, northwest India, and south Australia, are of the same sign in each case, as found by Walker (2) for the months of December to February.

Summer-pressure deviations.—In Figures 4 and 5 are represented the average pressure departures six months

earlier each year; that is, for June to August, 1882–1887 and 1918–1923. We see that the pressure distributions of June to August are recognizably related to those of December to February, in the corresponding years. The belts of deficient pressure in Figures 2 and 4 have the same general character, and many of the irregularities of the boundaries maintain their identity, though shifted somewhat in position. For example, the two northward tongues from the southern high-pressure area in Figure 4 persist six months later in Figure 2, and the well-marked deficiency separating them appears in both maps. In Figures 3 and 5 the similarity is less striking, and the central girdle of high pressure has shifted from the Southern Hemisphere in the southern winter to the Northern Hemisphere in the northern winter.

The most notable change from summer to winter is the complete reversal of pressure departures in the north Pacific in both series of years. For June to August, 1882–1887, pressure is above normal in practically the entire Pacific Ocean north of the Equator; six months later it is all below normal. The same complete change but in the opposite direction occurs from summer to winter in the years 1918–1923. No other large area shows such a complete reversal in both series of years.

Walker (**2**) found for June to August a strong positive correlation of pressure departures in South America, represented by Buenos Aires, Cordoba, and Santiago, with departures at Honolulu and Samoa, and negative correlation with northwest India, east Australia, and Mauritius. This "southern oscillation" is not consistently shown in the years here under discussion. In the first place, it would seem better to consider the east and west coasts of South America separately, since the departures at Buenos Aires and Santiago are of opposite sign both winter and summer from 1918–1924. There are other inconsistencies; in Figure 4 the relation of South America, as used by Walker, is negative with Honolulu and positive with northwest India; in Figure 5 deviations at Honolulu and Samoa are of opposite sign.

It may be noted that during the summers preceding the cold winters of 1883–1888 in the United States, pressure was high across the north Pacific, and preceding the warm winters, 1919–1924, it was low. This agrees with the result previously obtained (**3**) from a different group of years, consisting of eight warm and eight cold winters.

Temperature distribution.—The temperature departures, December to February, are shown in Figures 6 and 7. For the most part they may be inferred roughly but not in detail from the contemporary pressure anomalies. The northern area of excess pressure in the cold winters, 1883–1888, with centers over Manitoba and the Caucasus, was attended by subnormal temperature over the entire United States except Florida and the Pacific northwest, over most of Canada, and over Greenland, Iceland, western and southern Europe, and southern Asia, and by warm weather over northern Europe and Asia. It was also cold in central South America, northwest of the center of positive-pressure departure off the southeast coast. From 1919–1924 the winters averaged more than 2° F. warmer than normal in a large part of central North America from St. Louis to Eagle, and in nearly all of Europe, in conformity with the marked deficiency of pressure throughout northern latitudes. The reason for the cold area in the vicinity of Newfoundland is not apparent.

In Figure 7 the remarkable feature is the great preponderance of warm weather over all continental areas except Australia. It appears that a combination of all temperature records obtained would indicate that the world was definitely warmer than normal during this period, made up of the same three months in six successive years. Possibly the result would be different if data were evenly distributed over the entire surface of the globe.

Distribution of precipitation.—The distribution of precipitation in percentages of the normal is shown in Figures 8 and 9. For the most part, areas in which pressure, December to February, was above normal were areas of light contemporary rainfall, and those in which the pressure was below normal had more than average rainfall, but the related areas are far from coinciding exactly. In the United States there appears also a negative correlation between precipitation and temperature in both sets of years. The cold winters were wet and the warm winters were dry except in the southern plains region. It has recently been shown in greater detail (**4**) that this inverse relation prevails over a large part of the United States when all winters with temperature departures of 2° F. or more are considered, but that in other areas, including a portion of the southern plains, the relation is more frequently direct.

Both series of years were abnormally wet in Mexico, showing no relation to shifting pressure belts. Temperate South America shows a reversal of precipitation conditions from one series of years to the other more definite than its pressure changes. In Australia there is negative correlation between temperature and precipitation, as in the United States, and an alternation of conditions between northern and southern portions. From 1883–1888 there were dry and warm summers in the south and wet and cool at Port Darwin; from 1919–1924 it was wet and cool in the south and dry and warm in the north.

General remarks.—The cold years of 1884–1886 are connected by Humphreys (**5**) with the great volcanic eruptions of Krakatao, August 27, 1883, and Tarawera, June 10, 1886. This does not account for the fact that the cold began in the winter of 1882–1883; nor does volcanism account for the persistent warm period.

These warm and cold winters fit fairly well into the theory of the influence of sun-spot numbers upon world temperatures, and the periods are approximately one-half the 11-year sun-spot cycle. There was a maximum of sun spots in January, 1884, in the midst of the cold years but the numbers decreased rapidly in 1886 and 1887, while the temperature deficiencies continued into the spring of 1888. The warm period, 1918–1924, which prevailed in all continents except Australia, was a period of continuously decreasing sun spots, reaching a minimum in January, 1924. There was not, however, a very definite termination of the warm period in the Missouri Valley in 1924. After a slight downward tendency in the winter of 1924–25, the curve again moved rapidly upward. The sun-spot maximum of 1893 was followed by three cold winters as shown in Figure 1, and the minimum of 1913 by two or three warm winters, but in these cases, though the extremes of sun-spot numbers were more pronounced than in 1884 and 1924, the temperature changes in north-central America were neither so marked nor so prolonged.

Whatever the causes may have been, these maps show large areas of reversed pressure anomalies and a definite "change of climate" in one of these sets of years as compared with the other. The pressure deviations were not mere statistical abstractions, but were attended by real and important differences of temperature and precipitation over large areas. At Winnipeg the later series of years averaged 12.7° F. warmer than the earlier and over a large portion of Canada and the northern United States

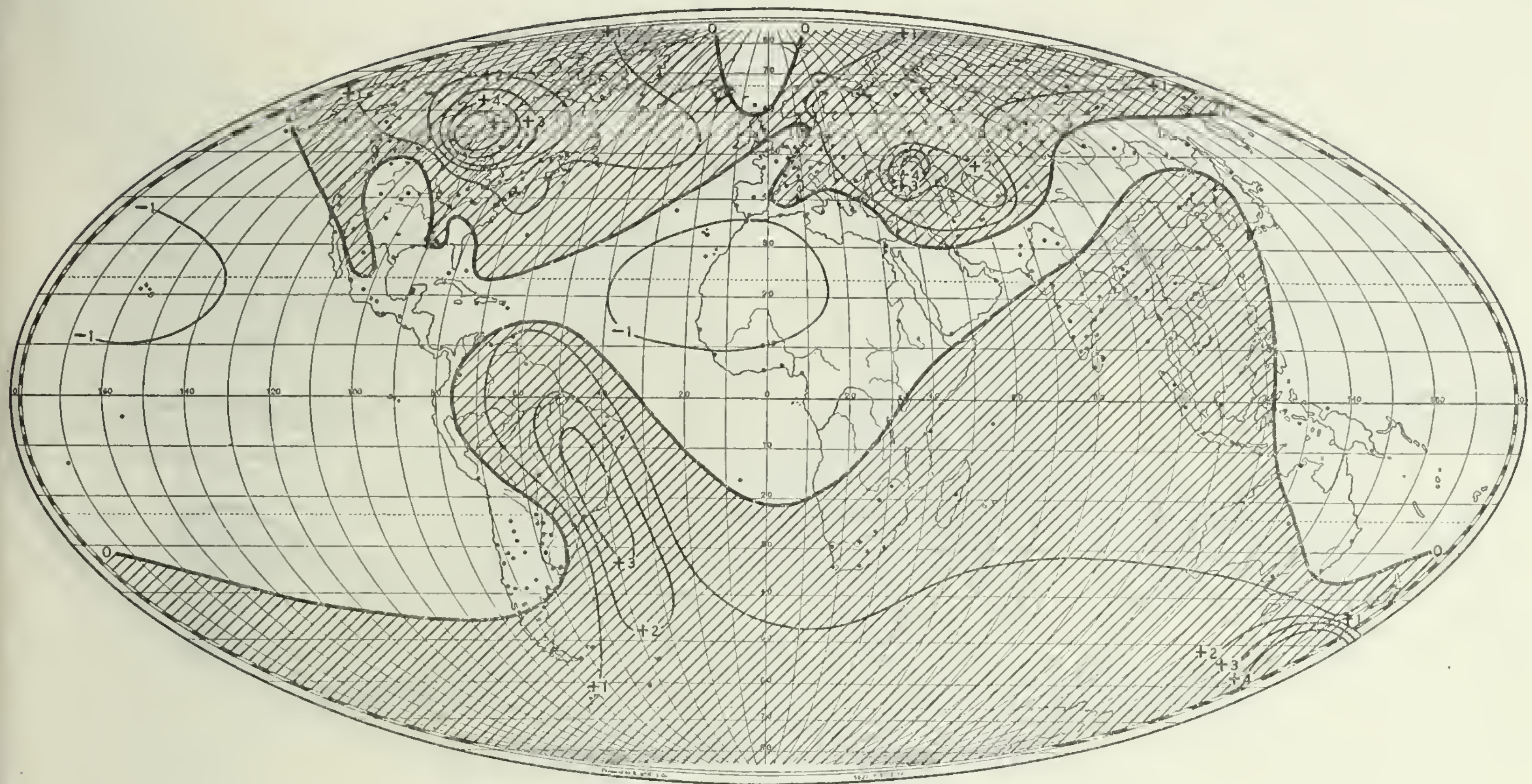

FIGURE 2.—Pressure departures, millibars; cold winters, 1883-1888

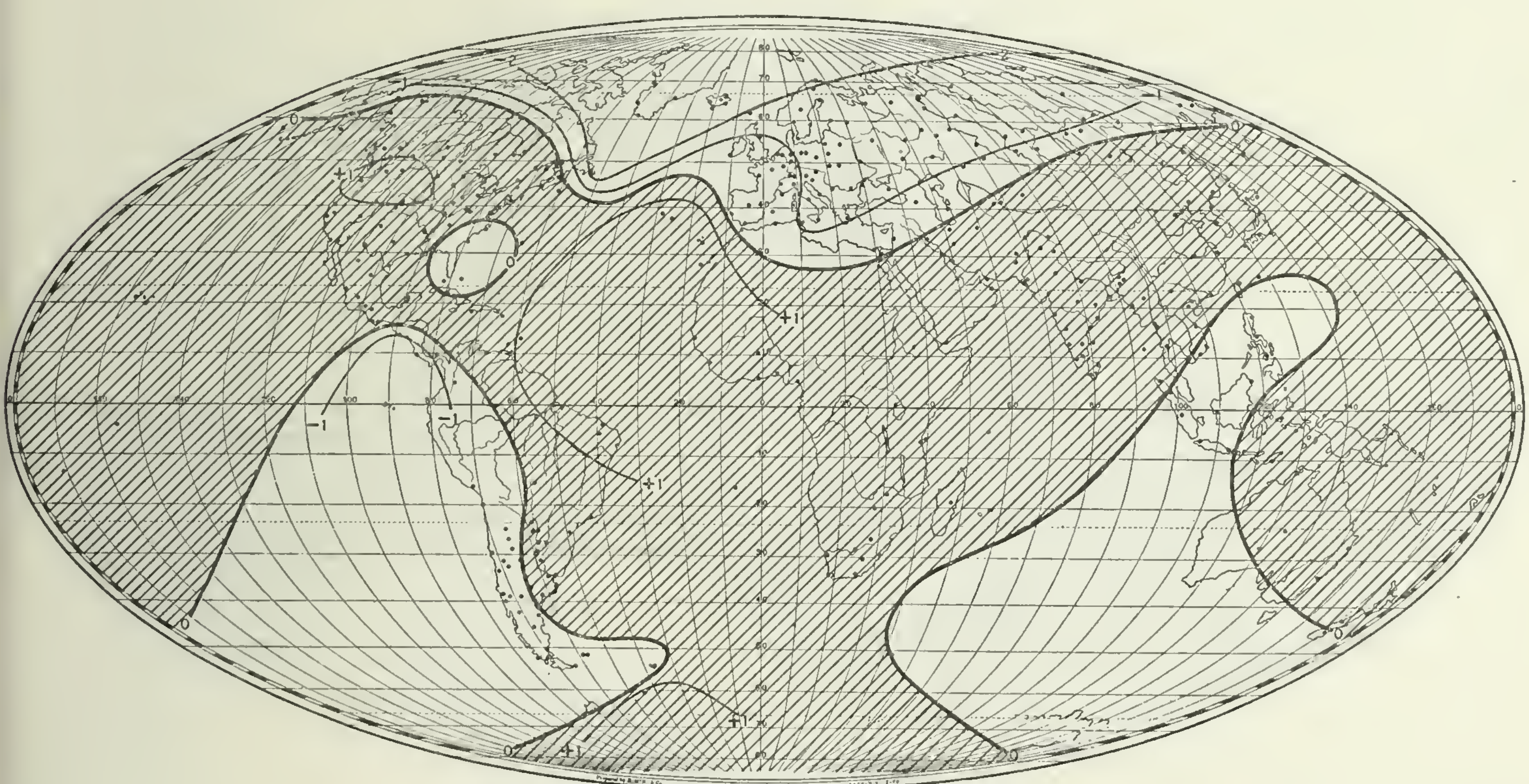

FIGURE 3.—Pressure departures, millibars; warm winters, 1919-1924

Figure 4.—Pressure departures, millibars; June–August, 1882–1887

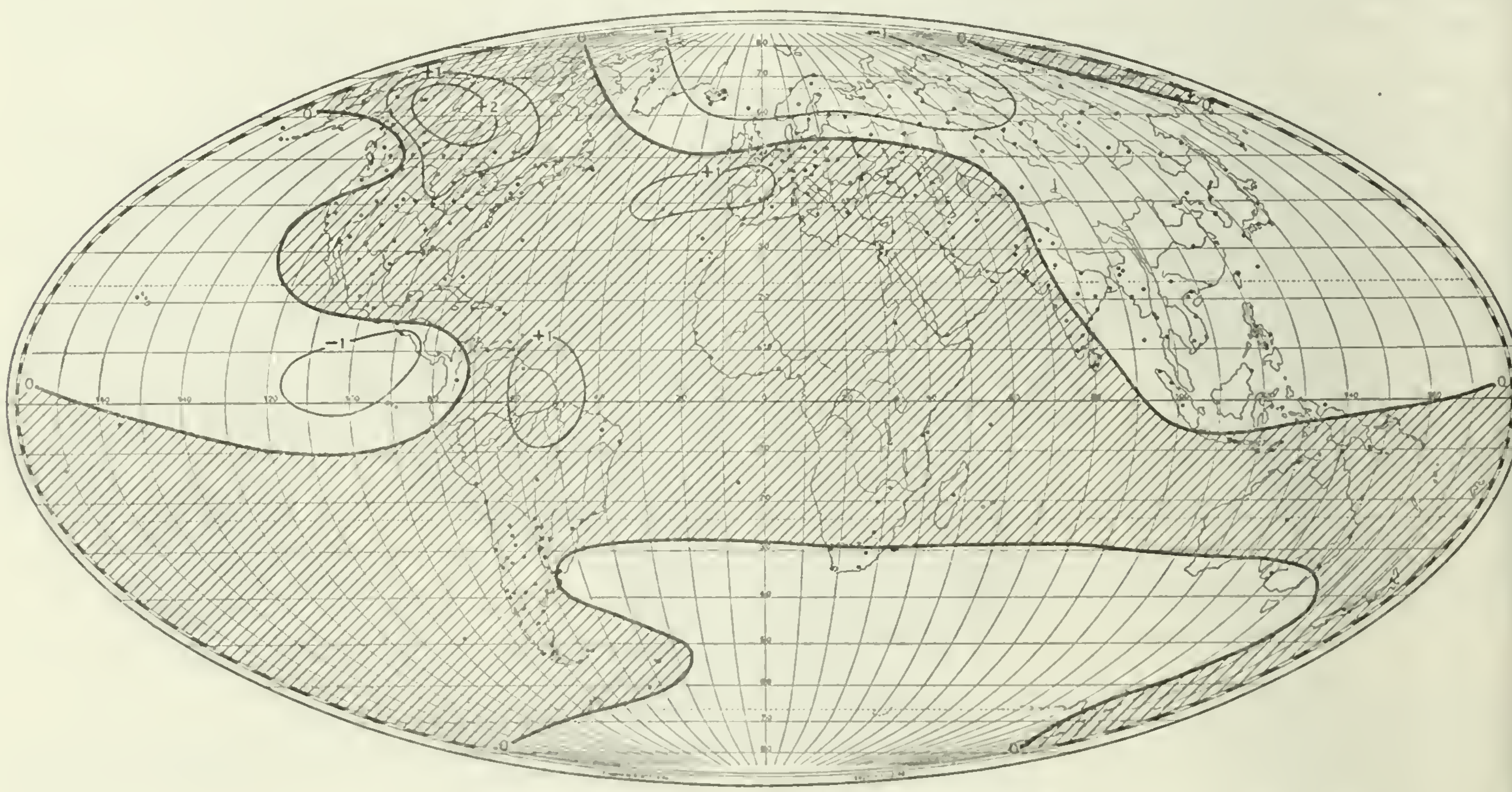

Figure 5.—Pressure departures, millibars; June–August, 1918–1923

Figure 6.—Winter temperature departures; 1883–1888

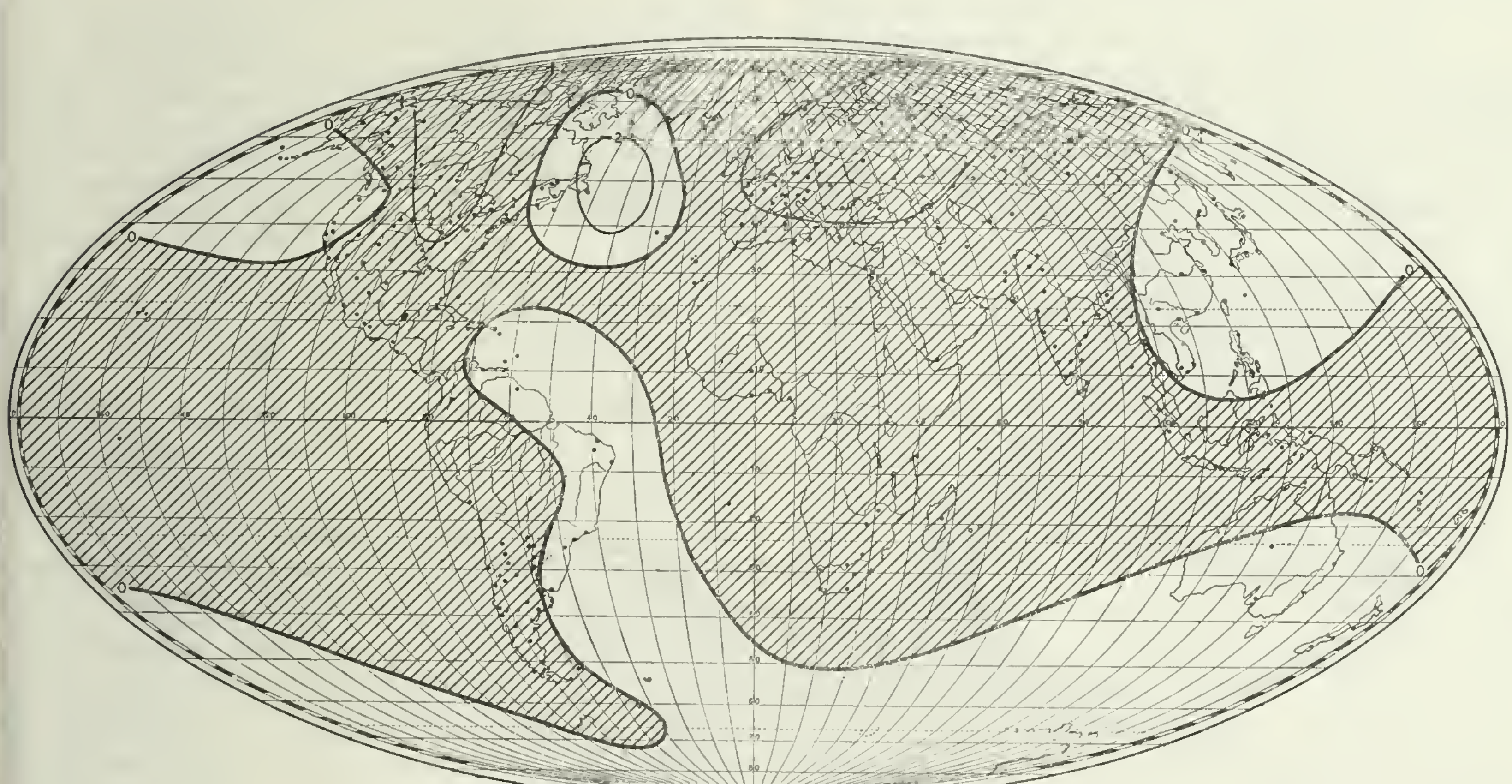

Figure 7.—Winter temperature departures; 1919–1924

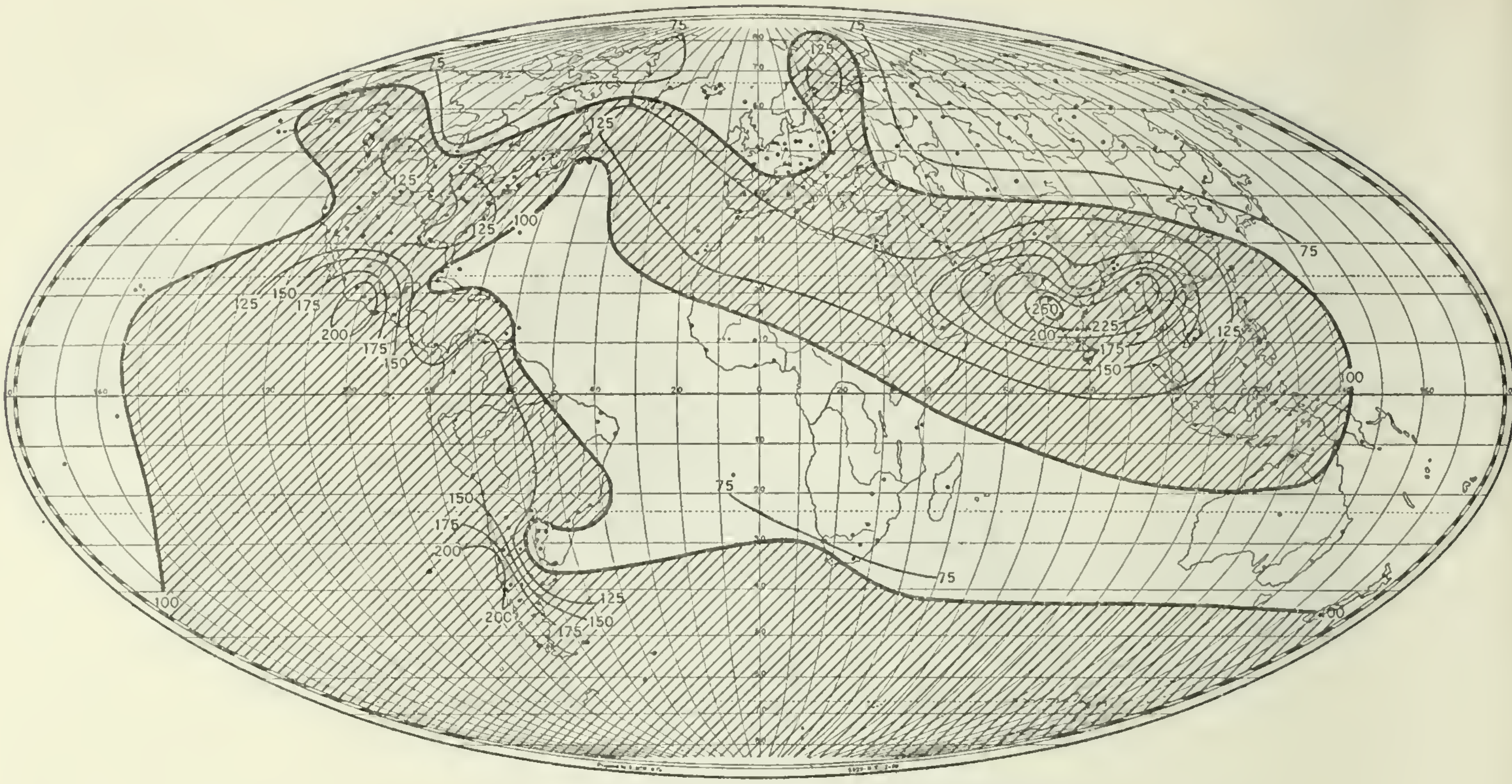

FIGURE 8.—Winter precipitation departures; percentages, 1883–1888

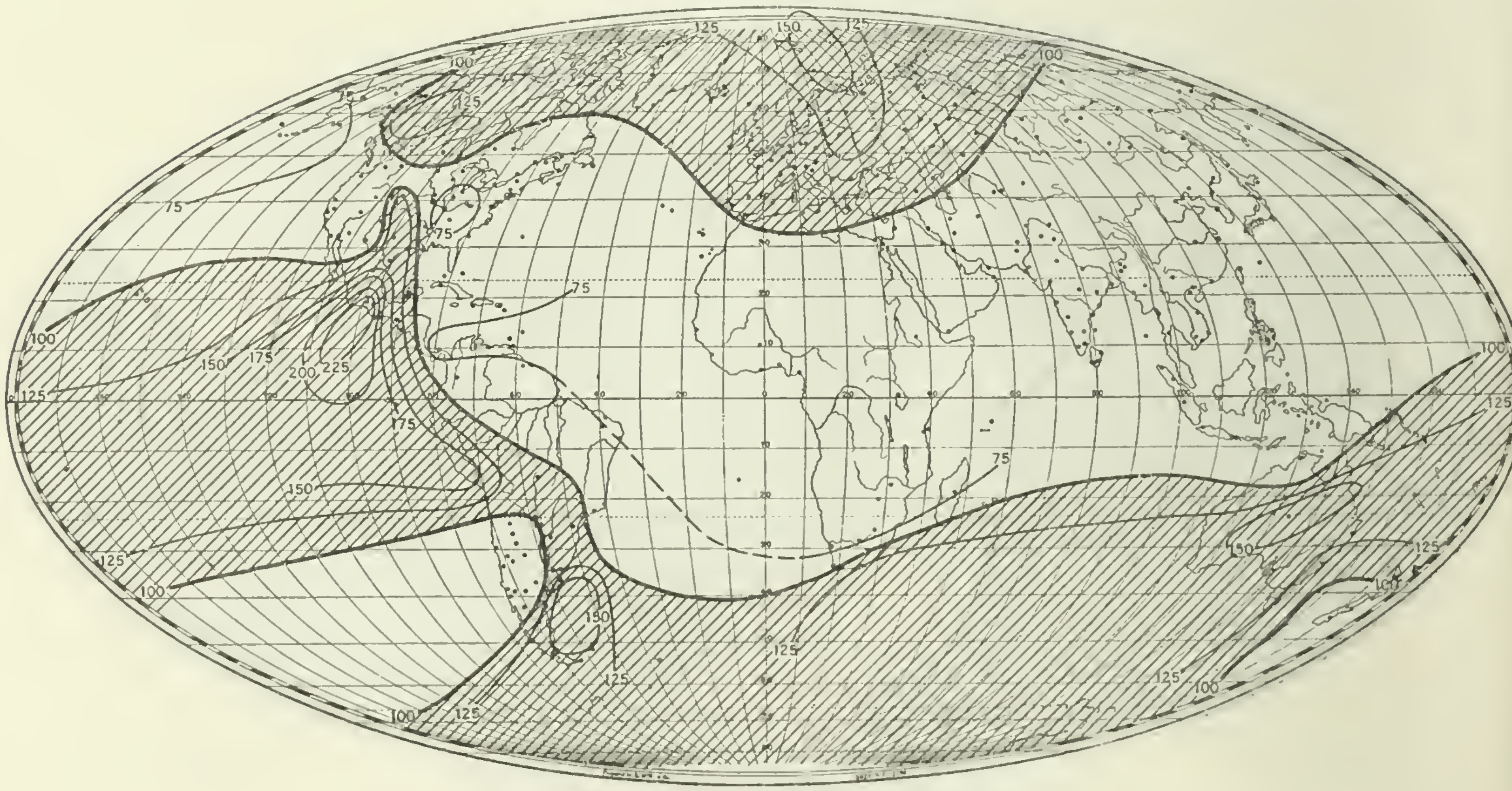

FIGURE 9.—Winter precipitation departures; percentages, 1919–1924

the difference exceeded 4° F. Also, over large areas the precipitation changed from 75 per cent of normal to 125 per cent. Significant changes in the general circulation, lasting about six years, are thus clearly shown.

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STORM WARNINGS ON THE GREAT LAKES

By GEORGE A. MARR, Vice President, Lake Carriers' Association

[Presented before the American Meteorological Society, Cleveland, Ohio, December 29-30, 1930]

Surrounded in our homes, in our offices and plants, and in every phase of our daily lives, as we are to-day, by a multiplicity of conveniences and utilities, we are prone to accept these aids and comforts as matters of course and look upon them with blasé indifference. We see them and use them with no interest beyond the comfort or convenience of the moment. The railroad, the motor car, the telegraph, the telephone, the radio, the moving picture, the iceless refrigerator, are merely things that *are*. Who stops to ponder over the research, experiment, study, labor, and organization that brought them into being or to develop them from primitive into complex and efficient instrumentalities of pleasure, usefulness, education, and better living?

This thought came home with striking force when I received the invitation to present a paper to your learned society on the subject of "Storm Warnings on the Great Lakes." I was aware that we have storm warnings, that they are indispensable to the safety of navigation, that the mariners place great dependence upon them and that we break into characteristic sailor vernacular if there is suggestion of their discontinuance before the last boat of the season is in winter quarters. And yet they have a history of development which has been obliterated from our consciousness by the long period during which the Government has performed for us this invaluable service. We have enjoyed the benefits of this service so long that we have looked upon it as complacently as you have upon the running water in your bathrooms, without thought of the engineer who designed and constructed the pumping station or the engineer who operates the pumps.

Failure of your automobile or your telephone brings dismay and harsh criticism. I can recall no instance of failure of the Weather Bureau to give advance warning of any serious storm, but it is conceivable that the results of any such failure might entail incalculable loss of life and property, and the importance of the service to safe navigation has always been regarded with the highest esteem. The Weather Bureau is entitled to the highest encomiums. No estimates can be made of the number of lives saved nor the millions of dollars worth of property preserved to transportation by their timely warnings of storms. It is no uncommon occurrence for dozens of vessels to remain in a harbor of safety in consequence of these advance notices from the Weather Bureau and I would be neglectful indeed if I failed to acknowledge, in this opportunity, the debt of gratitude which the sailor, the vessel owner, the shipper, and the traveling public owe to the faithful, devoted, and scientific service rendered by the officials and men engaged in this humanitarian calling.

The Weather Bureau was established by act of Congress in 1890 superseding a similar service inaugurated 20 years before by the War Department under a joint resolution of Congress becoming effective July 1, 1871.

Under this joint resolution of Congress, the Secretary of War was charged with the duties of taking meteorological observations and giving notice on the seacoasts and on the northern lakes by "magnetic telegraph and marine signals of the approach and force of storms." The Secretary of War was also authorized to establish signal stations at lighthouses and at such of the life-saving stations on the Lakes or seacoast as were suitably located for the purpose. Lake commerce has therefore enjoyed for 60 years a storm-warning service under the direction of either the War Department or the present organization in the Department of Agriculture.

When this service was inaugurated in 1871 the commercial traffic of the Lakes as measured by the statistics of commerce at the locks of St. Marys Falls had barely outgrown its swaddling clothes. The first lock at the Soo witnessed in its opening year, 1855, a freight traffic of less than 15,000 tons. This had grown in 1871 to nearly 600,000 tons carried in 573 steamer and 1,064 sailing ship cargoes. The commerce of the St. Marys Falls Canals now reaches a total of 100,000,000 tons in approximately 19,000 vessel passages, and the aggregate volume of the freight movement on the Great Lakes is around 150,000,000 tons carried annually in the navigation period of about seven and one-half months.

The adoption of the joint resolution of Congress establishing the storm-warning service was concurrent with the launching of the first bulk freighter on the Great Lakes. The steamer *Robt. J. Hackett*, the forerunner of the present type of ore, coal, and grain carriers, was launched in 1870. She was then the "leviathan" of the Lakes, of wooden construction, 211 feet in length and carried about 1,000 tons at the depth of water then prevailing in the connecting channels. While the type of vessel thus established has remained unchanged, the structural material has changed from wood to iron and then to steel, and the size of ships has grown to a length of 600 feet and over, with a carrying capacity sixteen-fold that of the *Hackett*. It may also be interesting to note that at the time the storm-warning service was inaugurated, sailing vessels constituted the major portion of the Great Lakes fleet. To-day there is not a sailing vessel left in the commercial trade of the upper lakes, the last one, *Our Son*, having foundered in the September storm of the past season. Incidentally this ship was built five years after the inauguration of the storm-forecasting service. Such has been the transformation of the lake fleet in 60 years. To a person not familiar with the Great Lakes the question may occur as to whether on these inland waters storms could arise of such force as to be of serious consequence to the large steel vessels of the present day. In this connection it is only necessary to refer to the storm of 1913 in which nine modern steel steamers were sunk without trace, and one, a 10,000-ton vessel loaded with coal, floated, bottom side up, on Lake Huron for several days, a striking manifestation of the power of a lake storm.

That the storm-warning service was undertaken by the Government primarily for the benefit of navigation is evident from the provision of the joint resolution of 1870 which authorized the establishment of marine signal stations, and also from the act of 1891 in which the duties, of the Weather Bureau are enumerated in the following order:

(a) Forecasting the weather.

(b) Issuance of storm warnings.

(c) Display of signals for the benefit of agriculture, commerce, and navigation.

Then follows the enumeration of a half-dozen other duties, but that the giving of warnings to commerce and navigation was the prime purpose of the Government is apparent from precedence given to these services in the language of the act.

It will be noticed that the joint resolution establishing the service under the direction of the Secretary of War required the Secretary to give warning of the approach and force of storms by "magnetic telegraph and marine signals." Since that time there have been remarkable advancements made in means of communication. The "magnetic telegraph" itself has undergone great development, not only by invention and improvement, but by expansion, so that communication by this means is now universal and the wire facilities for making forecasts and broadcasts have been greatly improved. But at best the "magnetic telegraph" affords means of communication only with land stations and with ships that are either in port or passing so closely to port as to be able to see the visual signals of impending storm. Vessels that have passed these sources of information before warnings were issued are at the mercy of the storm until reaching the next shelter, perhaps hundreds of miles distant, after the breaking of the storm.

The most marked, the most important, and I might say, the most dramatic step in the evolution of facilities for communication lies in the invention of the wireless telegraph. Neither the Weather Bureau nor the navigation interests have been slow to recognize the benefits of this and apply them to the paramount purpose of saving life and property at sea. There is rarely a violent storm at sea that does not bring to us through the press stories of ships in distress that have been succored and saved by other vessels which have received through the ether the magic S O S signal. While we of the Great Lakes can not "point with pride" to instances of this character that occur so frequently on salt water, we have nevertheless equipped many of our vessels with radiotelegraph instruments, not only to maintain business contact with the ships' officers but to enable them to receive timely warning of atmospheric disturbances and to seek whatever shelter their location and the force and direction of the storm may dictate.

The means of communicating warnings to the vessels at the present time are—

(1) The display of flag and lantern signals at land stations.

(2) The radiotelegraph broadcast.

(3) Broadcasts from radiotelephone broadcasting stations.

The distribution of storm information by the display of flags by day and lanterns by night is the primitive means of conveying the intelligence to ships' masters, and yet, in spite of the progress made by radio, these flag and lantern signals stand to-day as necessary to the safety of navigation as when they were inaugurated 60 years ago, and any thought of their discontinuance must be abandoned, or at least deferred indefinitely.

There are 115 such stations on the Great Lakes, 82 of which are maintained by our Government and 33 by the Dominion of Canada. These are located at strategic points in the various harbors or at conspicuous places on the banks of the connecting rivers, where vessel officers about to leave shelter may, seeing the warning, come to anchor until danger is past.

The ships of United States and of Canadian registry receive the benefit of the warnings displayed by either country. There are in the commercial trade of the Great Lakes 875 vessels, 581 of which fly the Stars and Stripes and 294 the British jack.

The act of June 24, 1910, amended by the act of July 23, 1912, makes it unlawful for any steamer of the United States or of a foreign country navigating the ocean or Great Lakes and licensed to carry or carrying 50 or more persons, including crew, to leave a port of the United States without radio apparatus of 100 miles radius, excepting as to vessels plying between ports not in excess of 200 miles apart.

Under the provisions of this act none of the lake freight vessels is required to be equipped and only a few of the passenger ships. The lake vessels, however, have been equipped to the extent of 224 out of the 581 American vessels and 84 of the 294 ships of Canadian registry, leaving between five and six hundred vessels that are not equipped to receive advices by wireless telegraph.

For communicating storm warnings to these radiotelegraph equipped vessels broadcasts are sent out at stated hours daily over the entire Great Lakes area. These broadcasts are sent in code from wireless telegraph stations at Duluth, Great Lakes, Chicago, Mackinac Island, Rogers City, Alpena, Cleveland, and Buffalo, giving information as to both prevailing and expected weather conditions, and warnings of storms whenever indicated.

In addition to this, a number of ships equipped with direction finders and a larger but unknown number on which officers or members of the crews have installed private "unofficial" receiving sets for entertainment are able to receive the radiophone broadcasts sent out daily by some 30 broadcasting stations at practically every hour of the day.

Such rapid development has followed in the wake of the invention of radio that the most fanciful dreamer can not envision the progress that is still to be made, and there is a disposition to look forward to the perfection of the radiotelephone, already in probationary service, before assuming the cost of equipping the remaining ships with the existing devices, with the current expense of operation and the probability of early abandonment for the substitution of improved equipment.

A deeply appreciated and highly commended additional service was established last year (1929) in an arrangement made through the Weather Bureau office at Duluth and the R. C. A. radiotelegraph station in that port. Under this arrangement reports are sent to Duluth from vessels on the open lake giving details of weather conditions prevailing in the vicinity of these vessels. This information is transmitted to vessels in port at Duluth and Superior, where weather conditions are often of marked difference in character from those prevalent on the lake. Not infrequently masters, warned of severe weather on Lake Superior and of which there was no indication in port, remained in sehlter until reporting vessels gave indication of moderation. So gratefully was this information received by masters that a similar arrangement was made during the season just closed to

inform masters at Sault Ste. Marie of the weather conditions on the east end of Lake Superior and the north end of Lake Huron.

As previously stated, the lake ships have been equipped far beyond the requirements of law, but the major portion of the commercial fleets of both United States and Canada is still dependent upon the flag and lantern displays. In addition to these unequipped vessels of the larger classes engaged in interlake trade there are numerous small craft, such as fishing vessels and yachts to which the flag and lantern displays are the only available warnings of threatened storm.

I have no hesitancy, therefore, in stating that no thought should be given at the present time to the withdrawal or material contraction of the primitive system of flag and lantern displays. On the contrary, if this service can be expanded to greater usefulness in the saving of life and property the study of the Weather Bureau should be directed to that end. For instance, these signals show merely that a storm may be expected from a certain point of the compass. If a simple revision of the code could be arranged to show the anticipated force of the expected storm, the additional information would be valuable.

I make the further suggestion that the Weather Bureau might render an added service by the forecasting of fluctuations in the lake levels, particularly in the vicinity of the shoal places governing the loading depths of the vessels. Some years ago Mr. Frank Jermin, the meteorologist of the Weather Bureau at Alpena, Mich., made an extensive study of the effects of barometric pressure on the lake levels and the currents created by the transit of the high and low pressure areas from one part of a lake to another. The merits of Mr. Jermin's deductions I am not competent to discuss intelligently with you gentlemen, but I have a distinct recollection that Mr. Jermin said that these water-level fluctuations could be forecast with reasonable accuracy about six hours in advance of their occurrence. If this be true, may I not recommend to my Weather Bureau friends that consideration be given to the issuance of advance information with reference to these fluctuations?

While the poet sings of the "bounding billows" and the "wet sheet and flowing sea," the mariner reads with much greater concern the indications of his barometer and the reports and warning signals of the Weather Bureau. The stories they tell may not be ever new, but the interest holds longer than it does in other Twice-Told Tales.

SIGNIFICANCE OF AIR AND SEA TEMPERATURES OBTAINED ON CRUISE VII OF THE "CARNEGIE"[1]

By Katharine B. Clarke

On the tenth of May, 1928, the nonmagnetic ship, *Carnegie*, sponsored by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, took departure from Newport News on its seventh cruise. It was possible on this cruise to inaugurate a complete meteorological program. From the middle of May, 1928, to the middle of November, 1929, except for days in port, air pressure, temperature and humidity, and sea temperature were recorded continuously and a definite effort was made to obtain as accurate records as possible. These *Carnegie* observations are particularly valuable because in some regions of the Pacific where the *Carnegie* cruised meteorological data of known accuracy are scanty if not altogether lacking.

Of the meteorological results which are now being compiled at the Department of Terrestrial Magnetism, those of sea and air temperature are the most complete and accurate.

A continuous record of sea-water temperatures at a depth of approximately two meters was obtained with a mercury-in-steel bulb-and-capillary type of sea-water thermograph with daily movement. Sheets were changed daily at Greenwich mean noon. Immediately before each change of sheet the temperature of the surface sea water was measured by the bucket method. This consisted in lowering a canvas bucket into the sea about two feet below the surface, quickly hauling this to the deck and measuring the water temperature by immersing a standardized thermometer in the bucket. The temperature so obtained was entered on the thermogram. In areas where the sea-surface temperature was changing rapidly, as in entering port or in calm weather, a mean of several bucket readings was taken.

The thermograms were scaled at every full hour local mean time. The differences between thermograph and bucket readings have been recorded, and these values, used as a correction factor, applied to the hourly thermograph readings to obtain true sea-surface temperatures. Bucket temperatures were higher than thermograph temperatures by 0°.8 C. to 0°.9 C. at lower sea temperatures and by 0°.2 C. to 0°.1 C. at higher sea temperatures. Comparing temperatures so obtained with the sea-surface temperatures measured at the oceanographic stations with standardized reversing thermometers a difference greater than 0°.5 C. never was found and at over half the stations the difference was less than 0°.1 C. Values of corrected sea-surface temperatures range from 6°.4 C, (43°.5 F.), recorded just south of the Aleutian Islands at 12^h July 8, 1929, to 30°.2 C. (86°.4 F.) approaching Pago Pago at 14^h, November 14, 1929.

For obtaining air temperatures several types of apparatus were used. The Hartmann and Braun electric-resistance multithermograph was installed for the purpose of obtaining lapse rates from deck to masthead. Three pairs of wet and dry bulb thermometers were installed at various heights above sea level—one pair in the Stevenson shelter on deck 12 feet (3.6 meters) above sea level, another pair in a ventilated screen just above the crosstrees on the mainmast 72 feet (21.9 meters) above sea level, and a third pair at the masthead on the mainmast 113 feet (34.6 meters) above sea level. These Thermometers were calibrated from time to time with an Assmann aspiration psychrometer.

The usefulness of these Hartmann and Braun records has been lessened because corrections for all the single thermometers can not be obtained. It is evident that the recorded values depend upon the efficiency of ventilation of the screens, which in turn is modified by direction and velocity of the wind. Unfortunately these wind-records were lost in the destruction of the vessel.

An examination of these Hartmann and Braun records has revealed a diurnal variation in the apparent lapse rates between deck and crosstrees (masthead-records were too incomplete for use). This must be due to heating of the deck-thermometer during the daylight hours.

[1] Based on a paper presented before the American Meteorological Society, Washington, May 4, 1931. Also cf. Brooks, Charles F. Meteorological Program of the Seventh cruise of the *Carnegie*, 1928-1929, Monthly Weather Review, May, 1929, vol. 57, pp. 194-196.

It has been possible to use these Hartmann and Braun records in correcting deck-temperatures for overheating, as will be explained later.

The Negretti-Zambra ventilating recording psychrometer was located in the Stevenson screen on the quarterdeck. The recording wet and dry bulb thermometers of this instrument were calibrated daily at Greenwich mean noon by means of an Assmann sling psychrometer. As soon as the wet and dry bulb temperatures were read off on the Assmann they were entered directly on the Negretti-Zambra thermogram. The Negretti-Zambra traces have been scaled at local mean time and hourly values corrected from Assmann reading have been obtained. From these values tables of hourly air temperature, relative humidity, and vapor pressure have been compiled.

Partly as a contribution to climatology and partly to study the diurnal variation of these elements, mean hourly values for areas have been computed. The areas, twenty-two in all, have been selected to represent regions within which small variations of temperature were found, or regions with like variations, such as the Gulf stream crossing. The periods of observation for the areas vary from 3 to 35 days.

As mentioned previously, an examination revealed a diurnal variation in the apparent lapse-rate between deck and crosstree temperatures recorded by the Hartmann and Braun instrument due undoubtedly to overheating of the deck thermometer during the day. Likewise a diurnal variation in differences of temperature recorded by the Hartmann and Braun dry bulb at the crosstrees and the Negretti-Zambra dry bulb in the deck screen has been discovered. The amplitude of this variation, however, is not as great as that of the differences in the two Hartmann and Braun thermometers presumably because the Negretti-Zambra instrument was better ventilated.

It has seemed justifiable to use these curves of differences for computing a correction to be applied to the daytime hourly mean temperatures by areas recorded by the Negretti-Zambra dry bulb. The curve of differences during daylight hours between Negretti-Zambra dry bulb on deck and Hartmann and Braun dry bulb at the crosstrees (means for areas) has been applied as a correction to the mean values of air temperatures. The result of applying these corrections is shown in Figure 6. (Dashed line represents mean air temperature as read from Negretti-Zambra dry bulb and corrected from Assmann readings. Broken line represents what the mean air temperature would be with a correction of the mean differences between Hartmann and Braun deck and crosstree temperatures applied to the Negretti-Zambra dry-bulb means. Full line represents air temperatures corrected for the mean differences of Hartmann and Braun crosstrees and Negretti-Zambra deck dry-bulb temperatures, which is accepted as the most accurate air temperature which can be obtained from the data available.) There are therefore corrected hourly means of sea-surface temperature and of air temperature for 22 areas.

Next a study of the differences between air and sea temperatures was undertaken. Of the daily means for the entire cruise it was found that in 61.5 per cent of the days the mean sea temperature exceeded mean air temperature. On the other 38.5 per cent of the days mean air temperature exceeded mean sea temperature. However, these daily means of air temperature were not corrected for overheating and are undoubtedly too high for actual air temperatures over the sea. Moreover the investigations were all carried out during a summer season or in the tropics and therefore do not represent true annual averages.

In comparing the mean differences for areas between air and sea temperatures, the mean air temperatures corrected for radiation were used. The difference of sea temperature minus air temperature was never as great as 2.°0 C. In only two areas, crossing the Gulf stream and in the Gulf of Panama, were mean sea temperatures more than 1.°0 C. higher than mean air temperatures. This large difference of 1.°6 C. over the Gulf stream may be attributed to the high water temperatures. A difference of 1.°5 C. between mean air and sea temperatures in the Gulf of Panama may be explained by the fact that during the entire 12 days of this series the wind was consistently from the southwest—from a region in which sea temperatures only a few hundred miles away were as much as 8° lower than in the gulf. Thus air considerably cooler than gulf water temperature was imported.

It is, also, interesting to note that of the means for the areas which include that part of the cruise from Japan to San Francisco, air temperatures appear to be slightly higher on the average than sea temperatures. Differences are small, from 0.°1 C. to 0.°7 C. The winds during this part of the cruise usually had a southerly component.

In one other area, that centered off the coast of Chile approximately on the western edge of the Peruvian current, the mean air temperature was 0.°11 C. higher than the rather low mean sea temperature here.

From the corrected hourly means for areas a study of diurnal variation has been made. From the literature concerning previous investigations of this subject it was expected that the diurnal variation in differences between air and sea temperatures would be small—about 1° C.—and that in general air temperatures would be lower than sea temperatures during the night and would approach and probably exceed sea temperatures during the day. Mean hourly air temperatures for areas corrected for radiation and for nonperiodic change, and mean hourly sea temperatures for areas corrected for nonperiodic change were used. For the areas which include that part of the cruise from Iceland to the Mid-North Atlantic (17° north, 38° west) and from Barbados to Callao none of the 24 mean hourly air temperatures exceeded the mean hourly sea temperatures. For all other areas the mean hourly air temperature at some time during the day rose higher than the mean sea temperature. However, when air temperatures not corrected for radiation were used in this comparison, for every area except that of the Gulf stream and of the Gulf of Panama air temperatures exceeded sea temperatures sometime during the day. This seems to indicate that if the effect of radiation could be entirely eliminated the mean daily air temperature would seldom exceed mean daily sea temperature.

It was noted that in some of the areas the air temperature exceeded the sea temperature only during the hours between 8 and 10 a. m. In others the air temperature rose above sea temperature about 8 or 9 a. m. and remained above until late afternoon (see fig. 7). A study for the cause of this revealed that in the areas which had an air temperature greater than sea temperature in the morning and then fell below the rest of the day, that the air temperature was at a maximum about 10 a. m. The most plausible explanation for this seemed to be found in the cloudiness records from the log extract and from some atmospheric-electric observations, which indicated that days included in means which had an early maximum were also days when the sky clouded over in the late morning and remained cloudy the rest of the day, thus producing an effect comparable to that of a mountain climate in summer.

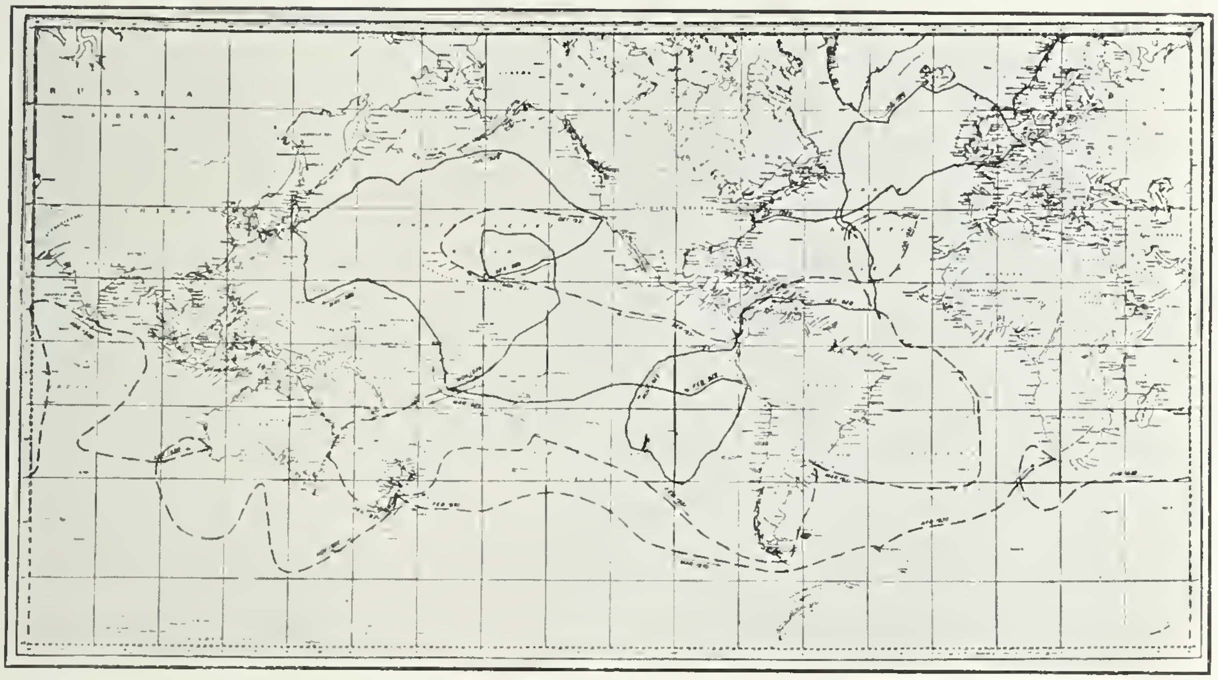


FIGURE 1.—Cruise VII of the *Carnegie*, May, 1928, to November, 1929 (broken line shows portion not completed)

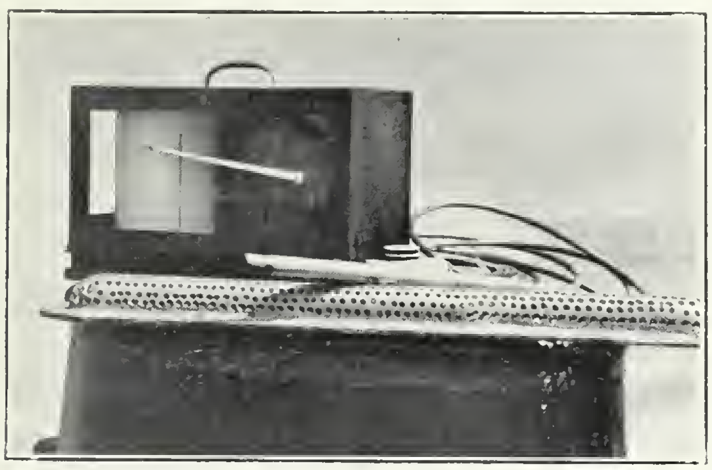


FIGURE 2.—Sea-water thermograph used on *Carnegie*, showing mercury bulb, metal shield, and recording mechanism

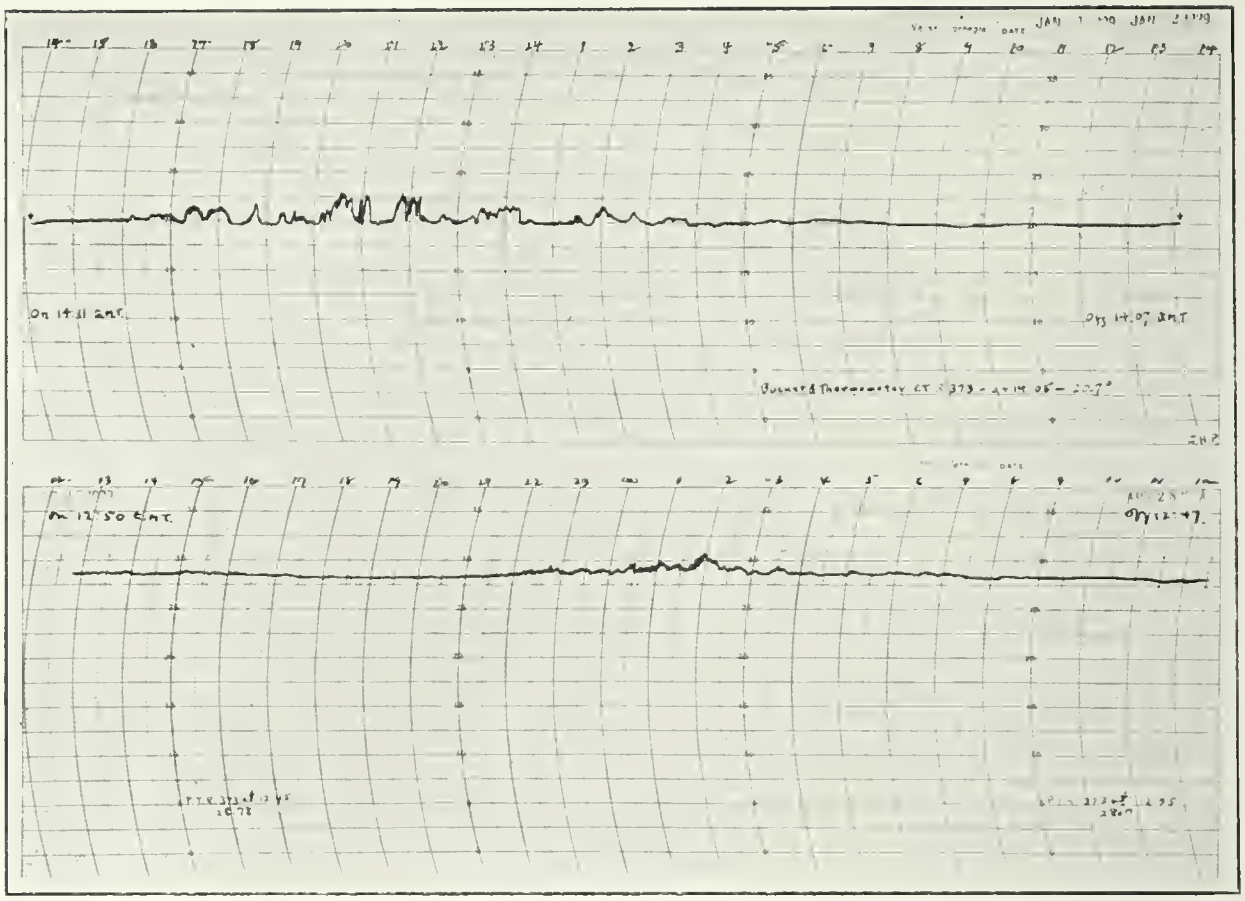


FIGURE 3.—Two thermograms from cruise VII of the *Carnegie* (upper one was obtained on the western edge of the Humboldt Current; lower one is typical of those recorded on calm days in the Tropics)

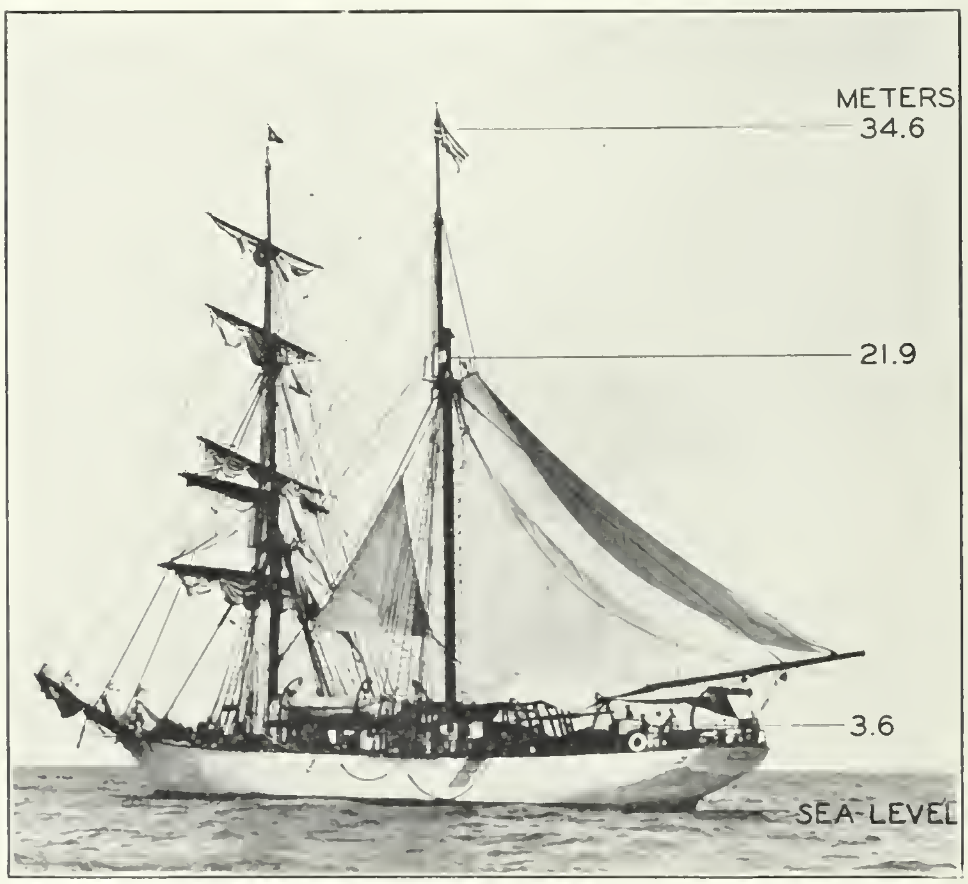


FIGURE 4.—The *Carnegie* showing positions of Hartmann & Braun wet and dry bulb thermometers

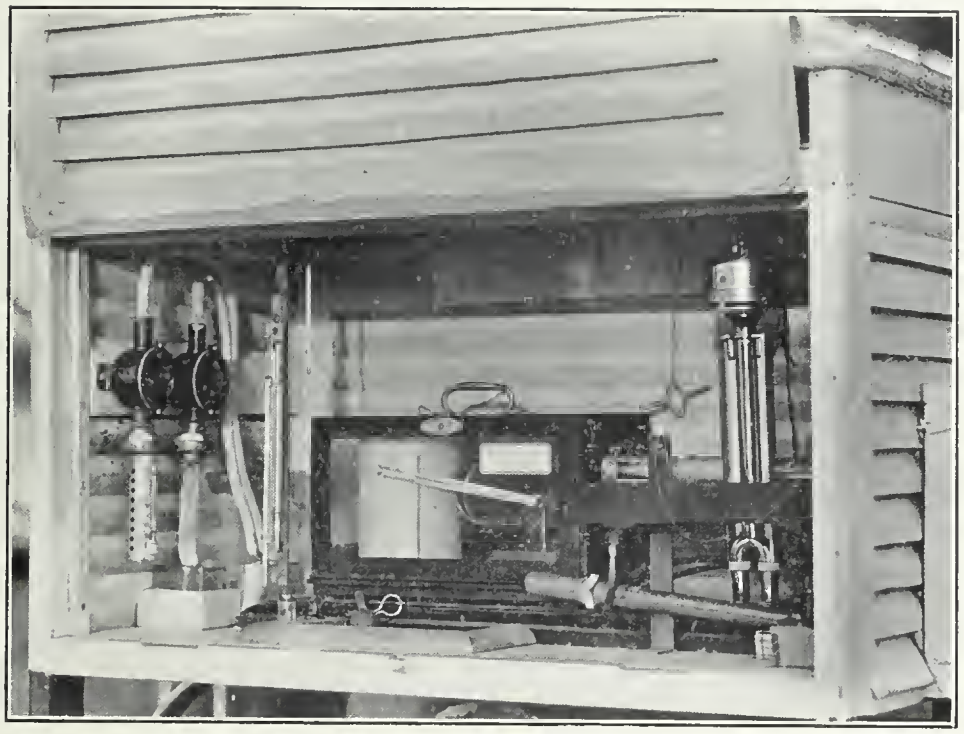


FIGURE 5.—Stevenson screen, open (on left a pair of wet and dry bulb Hartmann & Braun thermometers; in center, Negretti-Zambra ventilating recording psychrometer motor-box outside shelter; Assmann aspiration psychrometer at extreme right)

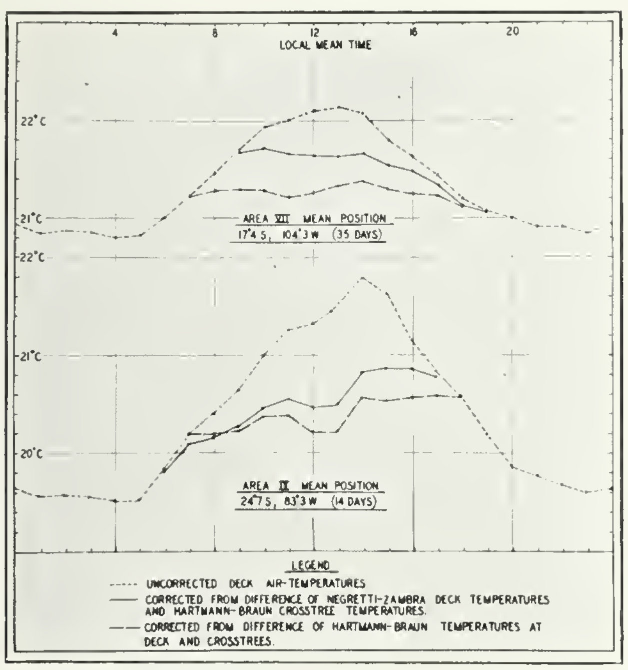


FIGURE 6.—Showing result of correcting excessive daytime temperatures recorded on deck, by means of the diurnal variation in differences between temperatures at deck and crosstree

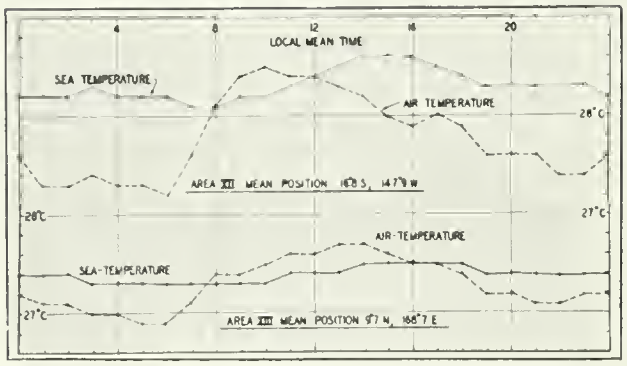


FIGURE 7. Typical diurnal curves of air and sea temperatures

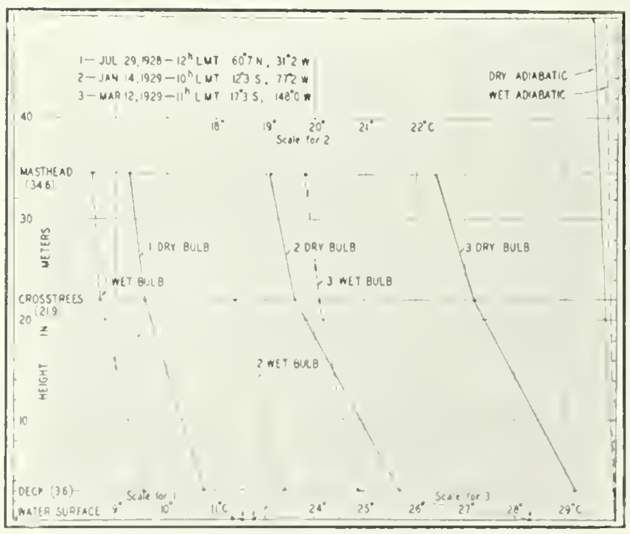


FIGURE 8.—Wet and dry bulb lapse rates

In order to determine to what degree lapse rates obtained by means of thermometers at different heights above deck are useful, the wet and dry bulb temperature at different heights on days when an Assmann calibration with the Hartmann and Braun thermometers was made, were plotted. These daytime lapse rates are shown in Figure 8. The most striking fact is that these rates are decidedly superadiabatic.

(1) July 29, 1928, at 12^h local mean time, off coast of Iceland: The dry bulb at the masthead was 1°.5 C. lower than the deck dry bulb, a lapse equal to four times the dry adiabatic. The wet bulb lapse was 1°.1 C. between deck and masthead or six times the saturated adiabatic. The weather was cloudy with a moderate NW. breeze, sea moderate with surface temperature of 11°.6 C.

2) January 14, 1929, at 10^h local mean time, entering the port of Callao: There was a dry bulb temperature lapse of 2°.1 C. from deck to crosstrees and of 0°.5 C. from crosstrees to masthead, a total lapse of 2°.6 C. in 35 meters or seven times the dry adiabatic. The wet bulb lapse rate was 1°.0 C. between deck and crosstrees or nine times the saturated adiabatic. Wind was SSE., force 3, weather cloudy, sea temperature 18°.8 C.

(3) March 12, 1929, at 11^h local mean time, approaching the island of Tahiti: The dry bulb lapse rate was 2°.0 C. from deck to crosstrees and 0°.8 C. from crosstrees to masthead, a total of 2°.8 C. or seven times the dry adiabatic. Wet bulb lapse was 1°.1 C. in 35 meters or six times the saturated adiabatic. Weather was squally with gentle NW. breeze. Sea-surface temperature was 28°.3 C.

If the deck readings are ignored the lapse rates between crosstees and masthead are respectively two, four, and six times the dry adiabatic. These are exceedingly steep, suggesting that even the crosstree temperatures may have been affected by radiation from deck, sails, and shelter. It is entirely possible that such lapse rates could exist—rates as high as ten or twenty times the dry adiabatic have been observed. Certainly these excessive lapse rates do not represent actual air conditions over the entire ocean for any length of time. It would seem impossible for such unstable conditions to exist throughout a layer of air 35 meters thick for any length of time over any great area.

The results of the study of air and sea temperatures obtained on the *Carnegie* indicate that it is possible to obtain entirely satisfactory sea-surface temperatures with the sea thermograph corrected by careful bucket readings. It seems very probable, however, that air temperatures obtained on a ship at sea, particularly in the summer or in the tropics are too high and do not represent actual conditions over the sea. Since differences between sea and air temperatures are usually less than 1° C., for purposes of studying the physical processes of the atmosphere it becomes necessary to have air temperatures accurate to a tenth of a degree. In order to obtain temperatures of such degree of accuracy methods must be devised for obtaining these continuous temperatures free from the effect of local heating. *Carnegie* data indicate that if air temperatures a few meters above the sea, free from the effects of insolation on the shelter, radiation and heated air could be obtained, it would be found that even the mean hourly air temperatures seldom exceed the sea temperatures. Certainly the sea experts a powerful temperature influence upon the atmosphere.

THE SELECTED-SHIP PROGRAM FOR OCEAN-WEATHER REPORTING BY RADIO

By Edgar B. Calvert, Chief, Forecast Division.

[Weather Bureau, Washington]

During the past two years the Weather Bureau has been actively engaged in furthering its share of a project, international in scope, intended to coordinate and improve the work of reporting meteorological conditions at sea by radio. It is not intended that the new scheme, so far as the bureau's own service is concerned, shall supersede the existing arrangement through which it secures by radio, chiefly for its own purpose, a considerable daily collection of reports from ships in the Pacific Ocean and during the hurricane season from ships in the South Atlantic, Gulf of Mexico, and Caribbean Sea. Though the new project is distinctively international in character and is the Weather Bureau's contribution to a worldwide program, it will serve to strengthen materially its own radio weather service from ships at sea.

Weather reports from ships have long been used in advancing knowledge of ocean meteorology and in supplying information concerning storms and other atmospheric conditions over the oceans for the benefit of navigation. In the last quarter of a century ships' weather reports have been collected by radio in increasing numbers, thereby enabling meteorological services to extend daily synoptic charts over the oceans and provide daily forecasts and warnings and synoptic weather information by radiobroadcast for use of ships at sea.

HISTORICAL

A majority of ocean-going vessels traverse waters from which weather reports are needed by the meteorological services of two or more nations. To make weather reports from a ship available to more than one meteorological service, a system of international exchanges must be set up or officers of ships are charged with much additional work in taking observations and forwarding reports to each service separately.

The need of coordination has long been recognized. More than 50 years before the invention of wireless communication, Lieutenant Maury sought more effective cooperation in ocean meteorological work. He attended the First Meteorological Congress in Brussels in 1853, and advocated the establishment of a uniform mode of making nautical and meteorological observations on board vessels of war. The result was that this conference undertook to use a uniform system of meteorological observations both on land and sea all over the world. High honors were bestowed on Maury both in this and other countries because of his work in the fields of oceanography and meteorology, but many may not remember that in 1868, he was appointed professor of meteorology in the Virginia Military Institute at Lexington, which possibly was the first recognition in this way of the science of meteorology by any institution of learning.

Development of wireless communication early in the present century brought many serious complications that did not enter into the program conceived by Maury.

The first wireless message received by the Weather Bureau containing a weather observation from a ship at sea was in December, 1905. Radio weather service from ships at sea was thereafter extended by the Weather Bureau and the weather services of other countries, keep-

ing pace with the installation of radio apparatus on ships. Such reports are now being received by the Weather Bureau at a rate in excess of 50,000 a year.

In order that a weather observation by radio may be promptly handled, a code is necessary. A coded message is much shorter, more economical in communication costs, can be transmitted with greater speed, and is handled more effectively in charting and rebroadcasting. Many different codes came into use, each meteorological service requesting information suited to its particular needs and utilizing a code best adapted to its own requirements.

Another difficulty was that each national weather service desired observations taken at hours most favorable for its daily routine of charting reports and issuing forecasts and information. The result was that officers of a ship traversing extensive oceanic areas were called upon to take observations at various hours, to forward reports by radio in different codes, and to record the observations on forms devised by each service, no two exactly alike.

The collection of ship reports and rebroadcasting of them for the benefit of marine and other interests, as well as international exchanges of reports by radio, were greatly complicated by the diversity of codes in use.

Early in the year 1928, Charles F. Marvin, chief of bureau, and Edgar B. Calvert, chief of the forecast division, representing the Weather Bureau, participated in conferences held in Paris and London for the purpose of working out a more definite and effective program of cooperation. The meetings were attended by officials of the meteorological services of the principal maritime nations of Europe. An agreement was reached whereby each country will arrange to engage a certain number of ships of its own registry on which observations will be taken daily at fixed hours and transmitted by radio. Ships are to be selected from those equipped with standard meteorological instruments and long-range radio apparatus. The number of ships of each nation engaged in the project will be in proportion to that nation's total tonnage of vessels over 100 tons. This program was adopted by the International Meteorological Organization in a conference at Copenhagen in September, 1929,at which Mr. Calvert was the Weather Bureau's representative.

Under the selected-ship plan there will eventually be 1,000 selected ships of all nations sending radio reports regularly during voyages at sea. Of this number about 225 will be of United States registry. These ships are specially selected from those having standard meterological instruments, long-range radio apparatus, and plying routes that are calculated to yield a satisfactory daily distribution of reports from the oceans.

The hours of observation of all selected ships will be identical in all parts of the world—midnight, 6 a. m., noon, and 6 p. m., Greenwich mean time, a latitude of one hour either way being allowed to meet exceptional conditions. Ships having enough watch officers may forward all four observations daily, but on most vessels only two will be radioed, giving preference to midnight and noon, Greenwich mean time.

Ship reports received at certain designated shore radio stations are exchanged by means of collective broadcasts of land and ocean reports in accordance with standard schedules. Meteorological reports are thus made available for mapping and forecasting purposes in many parts of the world within a short time after the observations are taken.

One of the most important features of the plan is that all ships' weather reports will be radioed in the same code, regardless of the nationality of the vessel sending the report or of the meteorological service to which the report is addressed. The essential portion of this standard international code, in groups of figures, with five figures in each group, is universal and invariable but each meteorological service has the choice of additional standardized groups to suit its peculiar requirements. The difficulty in securing adoption of a standard code acceptable to all meteorological services was one of the most serious obstacles in the way of coordination.

The scheme provides that selected ships of United States registry will send reports through foreign radio stations to European services when in the eastern Atlantic and selected ships of foreign registry will send reports to the Weather Bureau through United States coastal stations when in the western Atlantic. A vexing and difficult problem in the international program which concerned the payment of ship to shore tolls on these weather messages has been solved by the generous cooperation of the Radio Marine Corporation and the Mackay Telegraph & Radio Co., in the waiving of ship to shore tolls, regardless of whether the messages are transmitted to United States or foreign shore stations.

PROGRESS

Under an initial appropriation made specifically for the purpose, the Weather Bureau began in 1929 to engage ships in its North Atlantic selected-ship service. The number of United States ships so engaged is now 30. A code book for United States selected ships containing the new international code was issued in May, 1930. The work is done on a cooperative basis and the service is maintained in an efficient manner by frequent personal visits to the ships when in port by Weather Bureau representatives specifically assigned to that duty and by written acknowledgments of service performed. Similar progress has been made by other national meteorological services and radio reports from selected ships of other nations are now being received daily by the Weather Bureau.

Arrangements for international exchanges of ships' weather reports are being perfected. The Weather Bureau transmits twice daily in a radio bulletin for the benefit of European meteorological services, about 100 land station reports representative of weather conditions in the United States, Canada, Alaska, and the West Indies, and a selection of reports from ships in the North Atlantic and Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea. The British Meteorological Service has recently begun transmission to the Weather Bureau of twice-daily bulletins of a similar character containing ship reports as well as observations from representative European land stations to the Weather Bureau. All these broadcasts are now in general conformance with the international codes adopted in Copenhagen in 1929.

Supplemental appropriations have been secured for extension of the selected-ship service to the South Atlantic, Gulf, and Caribbean waters during the fiscal year beginning July 1, 1931. By this means, daily reports from ships in southern waters will be received by radio throughout the year, whereas in the past such observations for the most part have been forwarded by radio only during the hurricane season. It is hoped that appropriations will become available in future years for similar service in the Pacific.

THE RADIATION CONFERENCE AT BERLIN AND POTSDAM,[1] FEBRUARY 23–26, 1931

By H. H. KIMBALL

[Weather Bureau, Washington, D. C., April 30, 1931]

Minutes of the first three sessions have been abstracted by H. H. Kimball from a manuscript furnished by A. Ångström, R. Süring, and K. Büttner. Minutes of the last two sessions have been translated by W. W. Reed.

The first session of the conference was held in the meteorological observatory at Potsdam, on February 23. The following were present: A. Ångström, Sweden; W. Mörikofer, Switzerland; F. Albrecht, K. Büttner, P. Dubois, G. Falckenberg, K. Fuessner, H. von Ficker, W. Kühl, F. Linke, W. Marten, and R. Süring, Germany. At later sessions, T. Burgeron, K. Kähler, A. Defant, H. Hergesell, C. Müller, F. Schmidt-Ott, and K. Stuchtey were also present.

Dr. Ångström opened the session with remarks relative to the objects of the conference, and stated the reasons for giving atmospheric turbidity such a prominent place on the program. He then presented Dr. Süring as presiding officer during the session.

Professor Linke found himself in accord with Ångström in questioning Fowle's determinations of the scattering of solar radiation by aqueous vapor in the atmosphere. He held that the vital point of the discussion is whether the amount of turbidity shall appear as a factor ($I=I_o e^{-aTm}$) or as an additive term ($I=I_o e^{-am-\beta m}$). He also pointed out that the turbidity must be capable of easy and accurate determination, and be independent of the air mass.

Ångström considered it advantageous not to include atmospheric absorption in the measurement of turbidity. Also, in agreement with Büttner, the dependence of turbidity upon wave length is recognized. Therefore, he recommends that the definition of turbidity be in such form that the reduction to a known wave length is easily accomplished. The turbidity coefficient, β, fulfills these conditions, and under mean conditions is independent of the wave length. The dependence of the total turbidity extinction on the wave length is expressed by the exponent a in the term $\frac{\beta}{\lambda^a}$.

At the second session of the commission Linke, Dubois, and Fuessner again discussed the dependence of turbidity on the wave length, and Ångström emphasized the fact that by the use of suitable measurements and computations the turbidity factor, the total turbidity extinction, and also the amount of precipitable water above the station can be determined. A discussion on the use of Schott glass filters in actinometric measurements followed.

The third session met at 10:30 a. m. of February 24 in the room of the "Notgemeinshaft der Deutschen Wissenshaft" in Berlin. Professor Süring proposed that the morning session be given up to a discussion of the question "What apparatus or what method should one recommend for the polar year?" Emphasis was laid on the importance of measurements of the intensity of solar radiation with the sun at different heights, using radiation filters controlled by the Potsdam observatory, so as to insure uniformity of results at different stations. Ångström pointed out the importance of reducing the angular opening of the pyrheliometer to about 5°, or at least all observers should give accurate information on the size of the opening of their pyrheliometer. Upsala, Washington, and Potsdam were designated as points at which pyrheliometers might be standardized in known pyrheliometric units.

In the afternoon a new absolute pyrheliometer was inspected at the Physikalisch-Technischen Reichanstalt, at Charlottenburg.

Fourth session, Wednesay, February 25, 10:45 a. m. at the meteorological observatory, Potsdam.

The following subjects were discussed:

1. Discussion of the term air mass. By air mass there can be designated either the true air mass

$$m_b = \frac{b}{760} \cdot \text{sec. } z, \text{ or sec. } z.$$

In this sec. z is to be taken as the symbol for the Bemporad function. Both measures have their advantages. A decision (between the two definitions) was not reached.

2. After a review of all the σ determinations, the value $\sigma = 8.26 \cdot 10^{-11}$ was designated as the most probable, since both the most recent measurements as well as the theoretical calculations give this value.

3. Report of Doctor Bergeron, of Oslo, on the eye observations of the opalescent turbidity in the service of synoptics.

The following proposals were formulated for presentation to the international meteorological organization;

1. The measurements of direct solar radiation are to be organized in such manner that in addition to the total depletion of the atmosphere there can be calculated from them the turbidity free from selective absorption by water vapor. To this end it is recommended that all stations employ glass filters of the same composition and thickness. The meteorological observatory, Potsdam, is willing to procure and gage such filters. Special instructions on the nature and use of the filters will be prepared.

2. Since the investigations relative to a decision on a standard scale for pyrheliometric measurements are as yet uncompleted, it is recommended for the present to refer all measurements to the Smithsonian scale of 1913. Readings from instruments standardized in terms of the Angström scale can be reduced to the Smithsonian scale by the addition of 3.5 per cent.

It is recommended that the standard pyrheliometers to be used during the polar year be compared before and after the expedition at Upsala, Potsdam, or Washington.

In order to eliminate at a later date the falsifying influences of skylight in the measurements of direct solar radiation it is necessary to give, in addition to the type of instrument used, as exactly as possible the aperature conditions of the actinometer (length of tube, size of outer orifice, size of inner orifice, or size of the object-glass surface).

3. It is recommended that at favorably located polar stations, where there is available a sufficiently scientific personnel, there be carried out measurements of total

[1] To readers not familiar with recent literature on atmospheric turbidity, a brief statement of views held by different investigators may be helpful in interpreting the discussion at the conference.

Linke would include in atmospheric turbidity, T, all atmospheric depletion of solar radiation except that due to molecular scattering, which latter is easily computed from Rayleigh's equations. He represents atmospheric depletion by $e^{-a_1 Tm}$.

Ångström represents atmospheric depletion by $e^{-(a_1+a_2)m}$, in which a_2 is the coefficient of scattering due to causes other than gas molecules, and including that which Fowle found associated with atmospheric water vapor. He expresses a_2 in the form $\frac{\beta}{\lambda^a}$ in which β is the atmospheric turbidity. The term does not include depletion through absorption by atmospheric gases, principally by water vapor. Under average conditions Ångström finds $a=1.3$, which, in contrast with λ^4 in the expression for molecular scattering, indicates that the diameters of the scattering particles are appreciably larger than the diameters of gas molecules.

insolation and of effective outward radiation. The instruments used are to be adjusted to standard apparatus. Suggestions for carrying out such measurements will be specially prepared.

4. Attention is called to the value of measurements of clearness of air, color of sky, anomalous refraction (measurements of the dip of the horizon), twilight, earthlight (Nachtschein), and zodiacal light. Details on the methods of these measurements have been drawn up by Professor Maurer (Zurich) and Dr. F. Schmid (Oberhelfenswil, Switzerland).

5. Special instructions on eye observations of the quantity and character of opalescent turbidity will be drawn up by Doctor Bergeron (Oslo).

6. As the value of the radiation constant there is recommended

$$\sigma = 8.26 \cdot 10^{-11} \cdot \text{cal/cm}^2 \cdot T^4$$
$$(5.76 \cdot 10^{-12} \cdot \text{watt/cm}^2 \cdot T^4).$$

In conclusion Herr Mörikofer reported his experiences in the gaging of cadmium cells and the advantages presented by taking into consideration relations of measurements with and without the employment of Minos glass (as a filter). Later, Herr Kühl presented curves from his new recording filtered potassium cell.

On Thursday, February 26, from 5:30 to 7 p. m. there was discussion of the methods of measurements with the cadmium cell; those taking part were Messrs. Büttner, Dubois, Feussner, Kühl, Mörikofer, and Süring.

(Signed) A. ÅNGSTRÖM.
R. SÜRING.
K. BÜTTNER.

FLYING WEATHER IN THE CORPUS CHRISTI AREA

By J. P. McAULIFFE

[Weather Bureau Office, Corpus Christi, Tex.]

The "Corpus Christi area" as usually referred to by aviators in this section extends roughly from Beeville, 56 miles north, to Kingsville, 40 miles south, and George West, 70 miles west. In this small area there is considerable diversity of weather, usually effecting visibility and ceiling.

There are three elements most vitally effecting flying in this area, namely: Fog, wind velocity, and thunderstorms. These three handicaps to flying should be carefully studied by aviators in this area.

Records at the Corpus Christi Weather Bureau show that during the 44-year period, 1887–1930, inclusive, the average number of dense fogs has been as follows during the months indicated:

Month	Number of dense fogs	Month	Number of dense fogs
January	3	October	1
February	2	November	2
March	2	December	3
April	1		

During the other months of the year fog occurs so seldom that it is practically negligible.

A peculiar condition exists at Beeville. Fogs are much more frequent there, and within 5 to 10 miles each side, than they are at Corpus Christi. Many mornings when Corpus Christi and San Antonio report perfect visibility and ceiling, aviators run into dense fog at Beeville. Of course with weather reports from San Antonio and Corpus Christi at hand they fly high and soon come out into clear weather. Occasionally aviators have left Corpus Christi without first getting weather data, and in many of these cases they were forced to turn back when near Beeville, not attempting to fly farther, because they assumed that the fog continued northward.

The cause of these frequent fogs in the vicinity of Beeville seems to be due to the slope of the land eastward to the Gulf, the presence of San Antonio and Copano Bays that indent the coast line sharply in the latitude of Beeville, and probably also the Aransas River that flows past Beeville. These lowlands and water areas here cause air currents from the Gulf to flow westward, meeting the cold interior air, and causing fogs. In thickness and their local character these fogs resemble the mists and fogs of the eastern mountain regions. The frequency of these fogs leaves no doubt that a sharp temperature gradient exists in that locality, especially in the winter months. These fogs are not confined to any particular type of weather, but occur with high pressure, as well as when the barometer is low. They dissipate usually about 10 a. m., but occasionally persist until noon or the midafternoon. The average thickness of these fogs is 1,000 feet.

The second great handicap to safe flying is the wind velocity on this coast.

The writer's attention was first directed to the erratic wind velocities in this section by a letter from one of the officials of the T. A. T. Corporation. In his letter the official mentioned the fact that reports from San Antonio were frequently misleading, because the weather was subject to such erratic changes near Kingsville. He mentioned strong head winds as one of the annoying elements. This would be, of course, a strong southeast or south wind for the planes that were coming from San Antonio. The prevalence of these winds caused a readjustment of schedules by the T. A. T. It was noticed that the planes would enter these windy regions suddenly from a region that had given only moderate southerly breezes, and this windy condition almost invariably occurred within 10 miles of Kingsville. (The planes usually traveled on a course from San Antonio to Brownsville about 50 to 75 miles inland.) This strong wind that the planes encountered at this locality is the celebrated Corpus Christi sea breeze (1) that is always present when some atmospheric disturbance does not interfere with it. It extends for only a short distance inland, and for this reason is encountered only when near the Gulf waters. Kingsville is very close to Baffins Bay, a long narrow bay that extends westward from the Gulf for 30 or 40 miles. The sea breeze on this coast extends to a height exceeding 1,000 feet, and probably as high as as 2,000 feet, as observed by ceiling balloons and the movement of cumulus clouds. The sea breeze in the vicinity of Kingsville has about the same strength as at Corpus Christi and averages 16 to 25 miles per hour. Sometimes it reaches 30 miles per hour.

This annoyance can be avoided, somewhat, by aviators either going far inland and avoiding Kingsville, or swinging Gulfward north of Corpus Christi. The wind velocities are not so great on the Gulf beaches as they are on the shores of the bays. The sea breeze also causes another peculiar atmospheric irregularity, thunderstorms that are difficult to forecast.

From direct observation at Corpus Christi it has been found that thunderstorms occur two or three times more frequently at Robstown, 14 miles westward, than they

do at Corpus Christi. These storms can be seen forming during summer afternoons and sometimes the thunder can be plainly heard at Corpus Christi, while the sky is clear from the Gulf horizon to within 5 or 6 miles of Robstown. It is reported that this same condition occurs at Kingsville. The reason is, of course, convection. The swiftly moving sea breeze prevents the formation of these thunderstorms (2) near the bays, but just as soom as this breeze ceases convectional thunderstorms occur, just as they do in any interior section. Occasionally these storms cause hail, and generally dangerous squalls, so aviators are careful in this area to avoid them. They can easily be avoided by airplanes flying as close to the Gulf as possible, and this is generally the course advised during summer by all planes flying in this area. Sometimes the planes coming from San Antonio or Brownsville are caught unawares, and have to encounter these storms, but with available reports of storms prevailing in the interior, with clear sky near the coast, it is easy for pilots to steer a course that will avoid these dangerous phenomena. The severity of the coastal storms has been discounted by some writers who have witnessed thunderstorms in the Mississippi Valley or other interior regions. However, it should be remembered that while these thunderstorms are rather quiet, with the thunder generally high, they are very dangerous to airplanes, because they have very strong upward currents, erratic squall conditions, and often hail. As an illustration of the dangerous type of these coast storms, two incidents are cited here:

On the occasion of an aerocade in 1929 the Weather Bureau at Corpus Christi and Brownsville furnished information at intervals of two hours during the progress of the flight from Houston to Brownsville. At 1 p. m. the planes left Corpus Christi for Brownsville, with clear weather at Corpus Christi, and overcast at Brownsville. There had been a few thunderstoms during the morning. Near Kingsville the planes encountered rain; farther south thunderstorms were seen. All but 2 of the 24 planes turned back and returned to Corpus Christi. One of the planes that continued reached Brownsville safely, the other one was blown off its course, and landed in a desolate spot in Mexico 100 miles south of Brownsville.

The other case of note was a 4-passenger plan returning to Kansas City from Aransas Pass, 24 miles east of Corpus Christi. The weather forecast issued that morning from the Corpus Christi office was for local thundershowers. The pilot received this forecast by telephone from the local office, but nevertheless took off for his homeward flight. Within 10 minutes after the start he encountered a thunderstorm, attempted to fly through it, and crashed, killing all the occupants of the plane. This thunderstorm was one without much thunder, but from evidence obtained after the crash the plane was carried upward several thousand feet and dropped on the other side.

CONCLUSIONS

From the above stated facts it is seen that flying weather in the Corpus Christi area is practically uninterrupted during the five months, May to September, inclusive, in so far as the greatest hazard to flying is concerned—fog. During the other months of the year the elements to be watched are the strong and erratic winds on this coast, and thunderstorms.

Wet "northers" are also a great handicap to planes traveling northward. When they prevail the ceiling is low, sometimes below 700 feet and occasionally 500 feet. Careful pilots in this area generally ground their planes when one of these annoying "northers" is expected. On the average about three to five such disturbances will occur in each month, November to March, inclusive.

(1) Heckathorn, Charles E. Monthly Weather Review, June, 1919, pp. 413–415 Land and Sea Breezes in the Vicinity of Corpus Christi.

(2) Tannehill, Ivan H. Monthly Weather Review, Sept., 1921, pp. 498–499, Wind Velocity and Rain Frequency on the South Texas Coast.

PILOT-BALLOON OBSERVATIONS AT HAVRE, MONT.

By Frank A. Math

[Weather Bureau Office, Havre, Mont.]

Although numerous compilations of balloon and kite data have been published in the Monthly Weather Review, it was thought that some of the more or less interesting results obtained with pilot balloons at Havre, Mont., during a period of three years and five months would add another chapter for study.

Whenever permissible, two balloon ascensions are made daily. The hours of observation were 6 a. m. and 2 p. m. from the beginning, August 6, 1927, to March 31, 1930, after which the hours were changed to 4.30 a. m. and 4.30 p. m. to work simultaneously with other stations. While a total of 2,487 observations were possible, at two a day, during the period from August 6, 1927, to December 31, 1930, there were 2,392, or 96 per cent, actually made. The visibility recorded with each according to the scale, 0 to 9, as given on page 29, Instructions for Making Pilot Balloon Observations, was as follows:

Observations	Visibility	Percentage
1,149	9	48
658	8	27
337	7	14
119	6	5
61	5	3
57	4	2
11	3	1

This indicates a high per cent of the number of possible ascensions and, as a rule, good visibility, over the plains of central Montana. A further indication of good flying weather is the small number, 95 "no ascensions" in three years and five months, or less than 4 per cent of total possible. Snow was the cause of preventing 48 of these "no ascensions"; rain, 26; low clouds, 10; fog, 8; high wind, 2; smoke, 1. In this connection it may be said that occasionally during low temperature in winter, a light dry snow falls with visibility 5 or 6. At such times balloons can be observed to altitude 1,000 to 2,000 meters.

There were 773 balloons reached an altitude of 4,000 meters or higher, 42 reached 10 kilometers (6.2 miles) or higher; and 13 reached 11 kilometers. The longest time that any one balloon was observed was one hour and 25 minutes, reaching an altitude of 15,390 meters (9.4 miles) on March 15, 1929, the highest of record for this station. The highest velocity computed from any balloon observation was 45.3 meters per second (101 miles per hour) on December 24, 1929. One of the balloons was observed to a distance of 44,600 meters (27.7 miles) away from Havre. That was the farthest of record by observation.

The bottoms of the paper lanterns attached to the balloons during darkness are stamped with the name of

the station and date. Six of the lanterns were picked up by farmers in remote places and mailed back to this office. The one returned from the most distant point was found on a farm near Ray, N. Dak., 32 miles northeast of Williston, or about 300 miles east of Havre. Others returned were found as follows: 15 miles southeast of Malta, Mont., about 100 miles east-southeast of Havre; one on King Island, Missouri River, about 82 miles southeast; one crossed the International boundary about 4 miles into Saskatchewan, 65 miles east-northeast of Havre.

FREE-AIR WINDS

A table showing surface-wind frequency and frequency resultants was compiled from data taken from page 13, Form 1001, recorded by register for each hour of the day. The registration was made by anemometer and wind vane 44 feet above the ground. The 4-year period, 1927–1930, was used in this table in order that it may be used in comparison with those of higher altitudes which follow. In this Table No. 1, surface winds favor a westerly movement with southwest prevailing, except that during the late spring month of May and the summer months of July and August the prevailing surface winds are east. June has a close race slightly in favor of southwest. The velocities, as a rule, are light to moderate, average about 6 miles per hour. The highest velocities are from a westerly direction. They occur mostly in winter, although the highest surface wind of record occurred during a summer squall in June.

Another table of surface wind direction frequency for Havre was prepared by E. R. Miller from data for the 13-year period, 1891–1902, MONTHLY WEATHER REVIEW, July, 1927, page 310. The two tables are much in agreement for all directions except northeast and east, which appear to be in reverse order. This is probably due to the difference in location of wind vane. During the 13-year period two different locations are involved and both are different from the location of the vane used in the later tabulation. The resultants of the later table, computed by the same formula, show a greater south component than the previous compilation.

Three other tables were prepared showing the percentage of times winds were observed from eight principal points of the compass and the velocities of the winds from the respective directions as computed from pilot balloon ascensions observed by the 1-theodolite method subject to any errors by this method as explained by Reihle, page 628, MONTHLY WEATHER REVIEW November, 1920. The data were compiled for altitudes, 801 meters, 1,530 meters, and 3,060 meters above the surface during the three years and five months ended December 31, 1930. The surface of Havre is 762 meters above sea level; the longitude, 109° 40′ west; the latitude, 48° 34′ north.

At the 801-meter level (2,628 feet), Table No. 2, the westerly winds are more decided than at the surface. The prevailing east direction of certain summer months has fallen to a smaller percentage being overcome by westerly winds. However, the velocities of all directions show a considerable increase, about double the surface easterly winds and about four times the westerly. Reihle, on page 629, MONTHLY WEATHER REVIEW. November, 1920, states, "A rapid increase in velocity from the ground to approximately 500 meters occurs at all seasons; above this there is little or no increase to 1,500 meters and there may be a decrease." This is true also for Havre, see Table No. 5.

The data in Table No. 3 at 1,530 meters, (5,020 feet) show the prevailing westerlies gaining more in per cent of times especially in the winter months. The percentage of easterly winds at this level in the winter season, November-March, is small, although during the summer, April-September, the easterly winds maintain a good percentage. Gregg has pointed out, page 234, MONTHLY WEATHER REVIEW, May, 1922, "The more striking features are: (1) The greater percentage of easterly winds at all levels in summer than in winter * * *." The average velocity of all directions remains close to, or slightly less than, at 801 meters.

Table No. 4, data at 3,060 meters (10,039 feet), shows a still greater increase in the percentage of times of the prevailing westerlies and a corresponding decrease in the easterly directions. From November 1, to about May 1, the percentage of easterly winds is very small, practically no east or southeast during January to April inclusive, although during May and June and September and October, a small percentage of easterly winds at this elevation is recorded. The velocities show an increase in most cases above the other levels. The highest velocities are westerly; the average from southwest through west and north being 11.4 meters per second, while from northeast through east and south is 4.8 miles per second.

The mean-frequency resultants of free-air winds at Havre for the whole period of balloon records are:

Surface	S 75° W
801 meters	N 85° W
1,530 meters	N 84° W
3,060 meters	N 81° W

Table No. 5 is a summary of the above data arranged to show the variation of the velocity and frequency percentages of the eight wind directions for the four seasons of the year from the surface up to 3,060 meters. The results shown by these tabulations, as a whole, agree to a great extent with those outlined by Gregg, MONTHLY WEATHER REVIEW, May, 1922, and by Reihle, MONTHLY WEATHER REVIEW, November, 1920.

TABLE 1.—*Surface wind frequency, and frequency resultants, Havre, Mont., for the four years, 1927–1930*

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultants
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	°
January	3	8	17	1	1	35	18	16	1	S. 79 W.
February	5	8	17	0	1	37	16	15	1	S. 78 W.
March	6	8	21	2	2	31	14	15	1	S. 80 W.
April	6	9	22	4	4	27	14	13	1	S. 69 W.
May	6	12	25	5	5	21	12	13	1	N. 34 W.
June	4	8	22	5	6	25	16	13	1	S. 61 W.
July	5	12	24	6	6	16	16	14	1	N. 18 W.
August	5	12	24	4	5	22	15	11	2	S. 64 W.
September	4	11	20	3	3	25	18	13	3	S. 88 W.
October	5	8	20	1	3	29	18	15	1	S. 84 W.
November	3	9	20	1	1	34	17	14	1	S. 73 W.
December	3	9	20	1	1	34	17	14	1	S. 73 W.

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE CONVERTED FROM MILES PER HOUR

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	2.1	1.9	2.0	0.8	0.9	5.2	2.5	2.3
February	2.5	1.7	2.2	0.0	1.3	5.2	2.5	2.8
March	2.8	2.0	2.2	1.9	1.4	4.8	3.0	3.4
April	4.6	2.7	3.2	2.1	1.7	4.5	3.3	3.4
May	3.1	2.4	3.1	2.3	1.8	3.8	3.2	3.4
June	2.5	1.8	2.3	1.9	1.7	3.9	3.3	3.6
July	2.4	1.8	2.2	2.0	1.6	2.9	2.3	2.9
August	2.4	1.8	2.1	1.4	1.3	2.8	2.0	2.5
September	2.4	1.8	2.0	1.3	1.8	3.4	2.5	3.2
October	2.8	1.8	2.1	1.2	1.3	4.4	2.9	2.0
November	1.7	1.9	2.4	2.0	1.1	5.3	2.4	2.9
December	2.0	1.7	2.3	0.7	1.1	5.7	2.7	2.6

TABLE 2.—*Percentage of time wind was observed from the following directions at 801 meters above the surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*
January	165	5	3	1	1	3	10	38	39	0
February	150	7	1	1	1	1	22	31	36	0
March	166	8	5	4	2	4	18	35	24	0
April	164	10	4	6	9	4	19	34	14	0
May	174	7	8	9	13	9	17	24	13	0
June	163	4	7	9	14	4	15	28	19	0
July	178	10	7	9	8	9	17	24	16	0
August	226	5	5	10	11	9	17	24	19	0
September	220	9	4	7	7	7	14	29	23	0
October	226	7	2	2	10	4	21	37	17	0
November	209	4	2	2	5	4	14	39	30	0
December	215	2	1	1	2	4	14	46	30	0

AVERAGE VEOLOCITIES, MILES PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	7.9	3.3	1.9	1.8	5.4	5.9	13.8	12.3
February	8.6	4.2	2.7	3.5	4.7	12.2	13.7	11.2
Mracb	7.0	3.0	4.2	10.0	4.7	11.1	12.7	9.8
April	5.7	4.0	7.3	10.9	5.3	7.4	11.1	7.3
May	6.0	5.1	8.5	9.8	5.9	7.0	10.2	7.1
June	5.4	3.9	8.6	4.6	4.9	5.5	10.5	10.0
July	4.7	5.8	7.0	5.9	4.0	5.7	7.4	7.5
August	4.9	3.1	5.9	5.9	5.5	5.9	7.9	6.4
September	6.1	4.7	3.4	4.5	5.0	6.6	9.0	8.3
October	5.0	6.7	5.0	4.5	8.1	9.4	12.5	10.1
November	9.4	6.0	5.9	4.4	4.4	11.7	13.5	10.9
December	11.0	3.6	6.5	4.9	5.1	10.1	15.4	10.7

TABLE 3.—*Percentage of time wind was observed from the following directions at 1,530 meters above surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
January	133	5	1	0	2	1	10	33	48	0
February	125	6	0	0	0	1	11	37	45	0
March	140	9	1	2	0	1	14	44	29	0
April	144	3	2	3	6	6	15	42	23	0
May	160	9	8	3	6	6	19	35	11	0
June	153	6	2	7	6	10	16	35	18	0
July	169	5	5	5	5	10	24	31	15	0
August	216	5	2	2	10	10	21	30	20	0
September	196	8	2	2	5	11	18	30	24	0
October	201	5	4	3	3	4	12	48	21	0
November	174	5	0	1	1	5	9	45	34	0
December	175	3	1	1	1	4	7	39	44	0

TABLE 3.—*Percentage of time wind was observed from the following directions at 1,530 meters above surface; period August 6, 1927–December 31, 1930*—Continued

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	9.0	2.3	0	3.8	3.0	7.1	13.9	13.0
February	8.9	0	0	0	8.2	11.1	13.5	12.2
Marcb	6.4	7.2	6.9	0	7.4	9.9	13.2	10.8
April	8.1	4.2	5.1	9.7	5.0	8.0	10.0	13.0
May	6.7	4.1	5.6	5.3	6.8	5.5	9.8	6.9
June	4.3	3.0	6.9	4.9	5.5	6.4	10.1	9.9
July	5.6	4.7	2.9	5.6	3.6	5.8	8.5	6.2
August	3.4	6.4	2.2	4.8	5.0	6.0	7.4	7.0
September	6.8	3.8	4.7	4.8	5.6	6.7	9.6	9.9
October	5.8	3.5	3.2	4.5	3.1	8.6	11.5	11.8
November	8.6	0	10.1	3.8	5.9	9.4	13.2	13.5
December	9.2	3.2	2.3	3.4	6.4	11.1	13.6	12.7

TABLE 4.—*Percentage of time wind was observed from the following directions at 3,060 meters above surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
January	56	6	2	0	0	0	2	34	56	0
February	58	12	2	0	0	2	9	36	39	0
March	73	15	1	0	0	0	4	52	28	0
April	84	4	2	0	0	2	19	49	24	0
May	121	9	3	3	3	5	19	41	17	0
June	109	5	3	2	2	6	18	38	26	0
July	146	3	0	1	0	1	27	51	17	0
August	170	2	1	1	2	5	22	47	20	0
September	119	4	3	3	1	6	15	35	33	0
October	120	2	3	2	2	3	12	48	28	0
November	89	6	1	0	4	1	7	39	42	0
December	69	12	0	1	3	3	7	35	39	0

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	13.8	8.4	0	0	0	3.2	13.1	16.2
February	15.1	16.2	0	0	8.7	10.0	14.6	13.1
March	10.5	7.3	0	0	0	11.4	14.4	13.9
April	9.1	13.0	0	0	4.7	9.2	12.3	12.5
May	5.3	5.7	3.4	5.6	10.4	10.5	10.3	11.3
June	6.5	2.4	5.4	7.1	9.9	9.3	12.3	10.7
July	7.1	0	5.0	0	6.9	13.0	11.9	7.9
August	7.7	1.1	7.7	7.2	6.6	10.8	11.5	9.2
September	8.9	3.9	6.5	6.2	7.8	12.7	11.3	13.1
October	7.6	8.9	6.5	5.9	13.4	11.4	13.3	14.2
November	14.6	3.2	0	1.2	4.9	12.4	13.7	15.5
December	13.3	0	3.2	5.3	9.2	8.7	13.1	16.0

TABLE 5.—*Seasonal winds at different altitudes*

Altitude	North		Northeast		East		Southeast		South		Southwest		West		Northwest		Calm
	Velocity (m. p. s.)	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Velocity (m. p. s.)*	*Per cent*	*Per cent*
SUMMER																	
Surface	2.4	5	1.8	11	2.2	23	1.8	5	1.5	6	3.2	21	2.5	16	3.0	13	1
801 meters	5.0	6	4.3	6	7.2	9	5.5	11	4.8	7	5.7	16	8.6	25	8.0	18	0
1,530 meters	4.4	5	4.7	3	4.0	15	5.1	7	4.7	10	6.1	20	8.7	32	7.7	18	0
3,060 meters	7.1	3	1.2	1	6.0	1	4.8	1	7.8	4	11.0	22	11.9	45	9.3	21	0
AUTUMN																	
Surface	2.3	4	1.8	9	2.2	20	1.5	2	1.4	2	4.4	29	2.6	18	3.0	14	2
801 meters	6.8	7	5.8	3	4.8	4	4.5	7	5.8	5	9.2	16	11.7	35	9.8	23	0
1,530 meters	7.1	6	2.4	2	6.0	2	4.4	3	4.9	7	8.2	13	11.4	41	11.7	26	0
3,060 meters	10.4	4	5.3	2	4.3	2	4.4	2	8.7	3	12.2	11	12.8	41	14.3	34	0
WINTER																	
Surface	2.2	4	1.8	8	2.2	17	0.5	1	1.1	1	5.4	37	2.6	17	2.6	15	1
801 meters	9.2	5	3.7	2	3.7	1	3.4	1	5.1	3	9.4	15	14.3	38	11.4	35	0
1,530 meters	9.0	5	1.8	1	0.8	1	2.4	1	5.9	2	9.8	9	13.7	36	12.6	46	0
3,060 meters	14.1	10	8.2	1	0.0	0	1.8	1	6.0	2	7.3	6	13.6	35	15.1	45	0
SPRING																	
Surface	3.5	6	2.4	10	2.8	23	2.1	4	1.6	4	4.4	26	3.2	13	3.4	14	1
801 meters	6.2	8	4.0	6	6.7	6	10.2	8	5.3	6	8.5	18	11.3	31	8.1	17	0
1,530 meters	7.1	7	5.2	4	5.9	3	5.0	4	6.4	5	7.8	16	11.0	40	10.2	21	0
3,060 meters	8.3	9	8.7	2	1.1	1	1.9	1	5.0	2	10.4	14	12.3	47	12.6	23	0

EVAPORATION IN THE EASTERN CARIBBEAN

By C. L. Ray

[Weather Bureau Office, San Juan, P. R., February 10, 1931]

Dependable mean values of evaporation may be had, as a rule, from a comparatively short period of observations, namely 10 years, more or less. The reasons are obvious: The primary influences affecting evaporation are temperature, vapor pressure, and wind velocity under 20 miles per hour, meteorological factors with a greater tendency to repeat themselves by months or seasons than is true of rainfall. This is true in greater degree in the latitude of the eastern Caribbean than elsewhere, due to the steadiness of the easterly "trades" throughout the year and the uniformity of the temperature. The stations considered in the present paper are San Juan, P. R., lat. 18° 29′ N., period of record, 1917–1930; St. Croix, Virgin Islands, lat. 17° 46′ N., 1920–1930; and Kingston, Jamaica, lat. 18° 1′ N., 1924–1930.

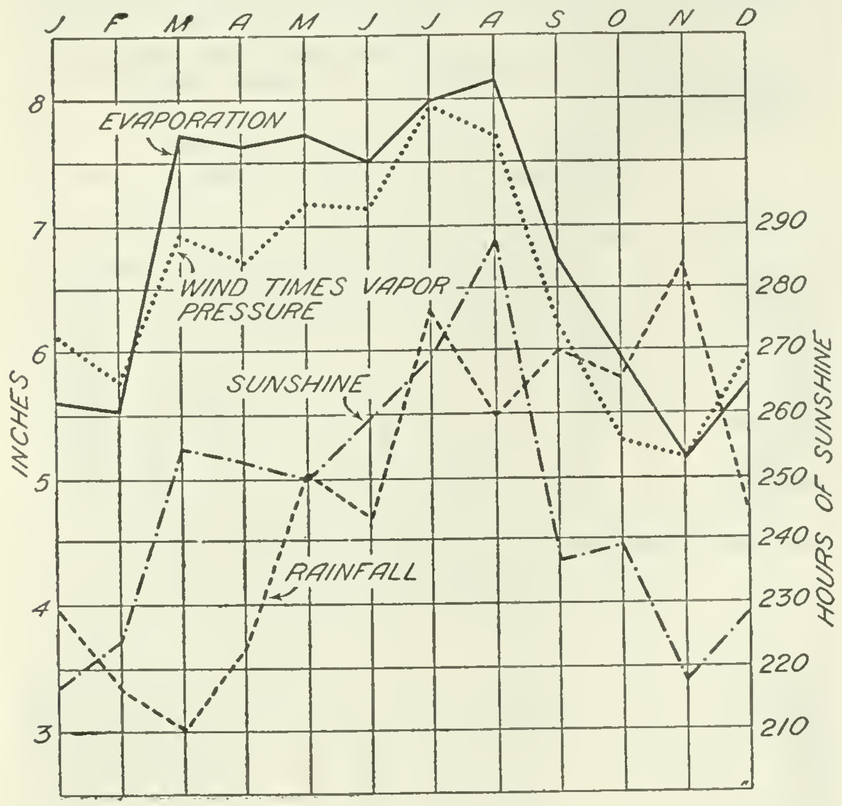


Figure 1.—San Juan, P. R. Evaporation (1917–1928) and related factors

At San Juan, 48 feet above mean sea level, the equipment consists of the standard evaporation pan, still well, and gage, of type similar to that in use in the continental United States since 1916. Daily observations at 8 a. m., E. S. T., include the 24-hour evaporation, rainfall, dry and wet bulb temperatures, hours of sunshine, and wind movement. The anemometer is placed at the surface of the water. Records of the average evaporation together with related data appear in Table 1, covering the three stations mentioned. In Figs. 1 and 2, graphs of the San Juan and St. Croix record are based upon Table 1, except for the omission of the years 1929–30 from the San Juan averages to allow for a comparable time period of wind mileage.

Referring to the monthly and annual values (not included in the published text), the maximum annual evaporation occurred in 1917, amounting to 88.988 inches, the secondary maximum in 1918, 87.724 inches. Wind mileage in 1917 and 1918 was between 47,000 and 49,000 miles, in 1917 being the second highest mileage on record and in 1918 the third greatest. The extreme maximum mileage occurred in 1922, exceeding 51,000 miles, during which year evaporation amounted to 82.133 inches. The year of least evaporation was 1930 (71 inches) for which period exact wind movement at the ground level is not available. The second and third lowest evaporation years were 1925 and 1927 during which occurred the extreme minimum and third lowest mileage. The effect of the wind factor is thus well defined in most instances. The maximum monthly evaporation occurred in July, 1917, amounting to 10.089 inches, the maximum wind mileage also occurring in the same month (6,323 miles); the least evaporation occurred in November, 1918, 3.999 inches, comparing with the low wind movement of 1,895 miles.

In the graph, Fig. 1, supplementing the evaporation and rainfall is shown the trace of monthly wind movement times the vapor pressure deficit, using the dry bulb and dew point vapor pressures in obtaining the latter value. A trace of the monthly variation in hours of sunshine is likewise charted. Both rather closely parallel the line of evaporation through the year. In the equation of Fitzgerald (Monthly Weather Review, 1904, Evaporation Observations in the United States, by H. H. Kimball) $E=0.3984\ (e_s-e_d)\ (1+.0208W)$ where e_s-e_d equals the vapor pressure deficit and W the wind mileage at the surface of the water, respectively, we obtain an evaporation some 25 per cent in excess of the measured readings at San Juan. The monthly values for this equation are included at the foot of Table 1. The rainfall totals at

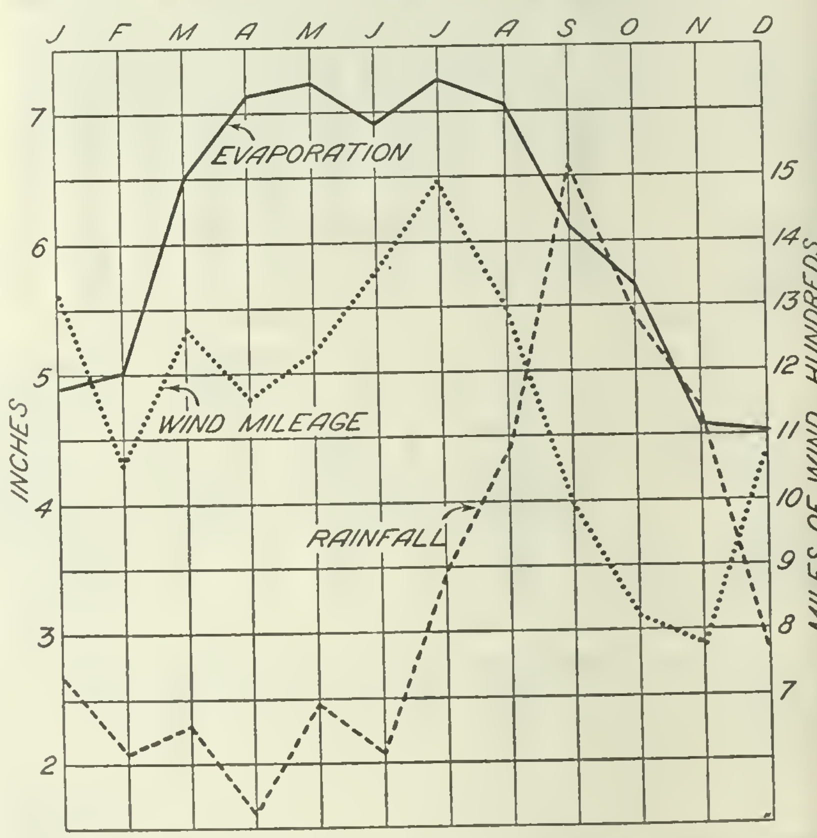


Figure 2.—St. Croix, Virgin Islands. Evaporation (1920–1930) and related factors

the station exceed evaporation in November, practically balance it in October, and are markedly below it through the other months. The greatest difference occurs in March with 4.6 inches excess of evaporation over rainfall.

The Christiansted, St. Croix, Virgin Islands, station is maintained by the Weather Bureau as a cooperative station. It is not equipped with a sunshine recorder,

nor are readings made of the wet-bulb temperature, vapor pressure, or humidity, but otherwise it is of the standard evaporation type, readings being made daily, including dry temperature, and wind mileage at the water level. Referring to Table 1 it will be noted that extreme monthly and annual values agree in general with the extremes at San Juan. Uniformly lower evaporation amounts, compared with San Juan, are accounted for largely, it would appear, by the lower wind movement. The elevation of the station is 25 feet above mean sea level, the lower wind velocities evidently due to local peculiarities of topography and exposure. The maximum evaporation at the station is registered as a rule in July, the minimum in November and December. The extreme maximum wind mileage occurs in July, the extreme minimum in November. Rainfall exceeds evaporation in September and November, approximately equals it in October, while falling well below in the remainder of the year. Fig. 2 shows the graphical picture of St. Croix evaporation over the 11-year period.

At Kingston, Jamaica, the data consist of monthly and annual measurements of evaporation over a period of seven years (1924 to 1930), including mean temperature and rainfall. The mean annual rainfall is less than 25 inches. Kingston is 59 feet above mean sea level. Wind movement is comparatively lower than that obtaining at San Juan and probably more nearly comparable to conditions at St. Croix. The vapor pressure deficit as indicated from the records available for a single year, 1901, show higher values than occur at San Juan, as would be supposed, in harmony with higher temperatures and a generally drier climate. Comparing the monthly values of the vapor pressure deficit for the year 1901 with the average monthly figures of evaporation (seven years), we find, as would be expected, extreme maximum evaporation values occurring in April and May, in coincidence with markedly larger vapor pressure deficit in those months. In Fig. 3 comparative data for the seven years (1924–1930) are given for Kingston, St. Croix, San Juan, and Balboa Heights, Canal Zone. The influence of the dry winter period at Panama is shown in the high evaporation values during the months of January to March, inclusive.

The excessive evaporation in the eastern Caribbean area is of course quite largely the result of the steady trade winds throughout practically all the year and the long daily periods of sunshine and high temperatures. The loss of moisture from land areas would be a serious problem for agriculture but for the frequent rains that occur in much of this section. In Porto Rico droughts are not generally of severity except on the south side of the island. The mountainous interior, extending from east to west, separates the area on a 70-30 basis, moisture-bearing winds leaving the great part of their precipitation on the 70 per cent northern side with consequent normally light rainfall south of the divide. The hurricane season frequently proves a boon to the latter portion of the island if not actually extending its influence farther north. Thus, tropical storms, passing to the south of Porto Rico, often result in beneficial rains on the south side of the island without damaging winds affecting the area. Irrigation however is the main dependence through much of the south portion. Evaporation is probably considerably greater than in the northern part, due to the drier atmosphere, greater amount of effective sunshine and higher temperatures.

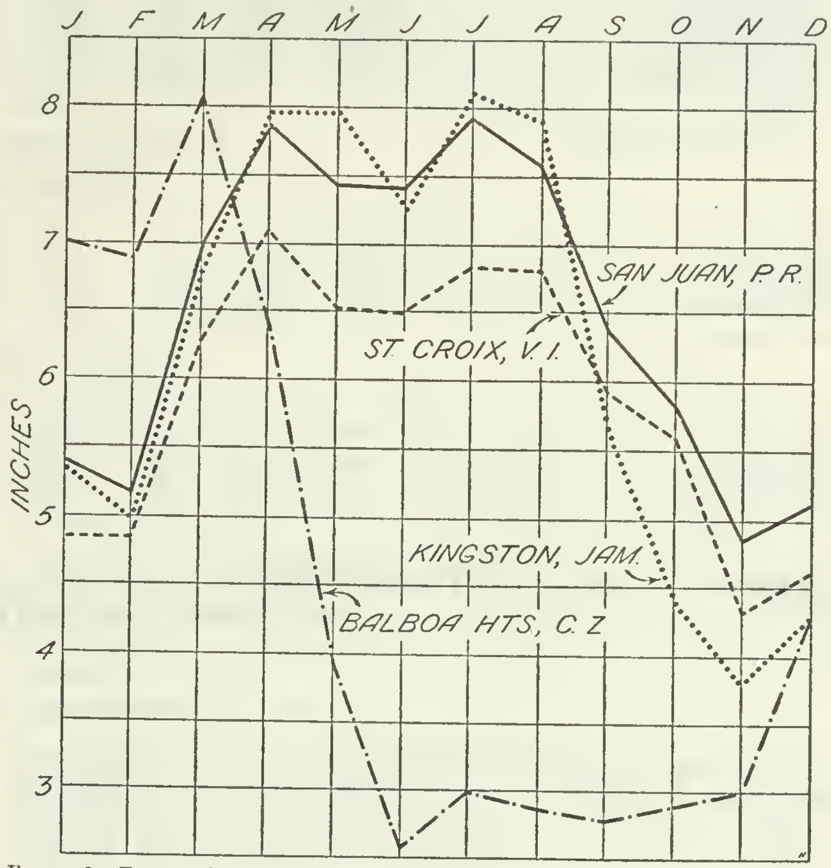


FIGURE 3.—Evaporation (1924–1930) San Juan, P. R., St. Croix, Virgin Islands, Kingston, Jamaica, and Balboa Heights, Canal Zone

TABLE 1.—*Evaporation and related factors*

SAN JUAN, P. R. (1917–1930)

[Lat. 18° 29′ N., long. 66° 7′ W.]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Evaporation	5.558	5.533	7.615	7.848	7.743	7.427	8.143	8.053	6.615	5.870	5.081	5.462	80.948
Wind mileage	3,975	3,397	4,089	3,567	3,401	3,407	4,322	3,801	2,561	2,106	2,366	3,723	40,716
Rainfall (inches)	4.11	3.15	2.90	3.32	5.12	4.65	5.74	5.50	5.95	5.41	6.37	4.64	56.86
Mean temperature	74.5	74.5	75.0	76.2	78.6	79.3	79.6	80.2	80.2	79.6	78.0	75.9	77.6
Vapor pressure deficit	.158	.160	.211	.230	.248	.245	.237	.248	.237	.218	.198	.177	----------
Sunshine hours	218	224	254	252	249	259	269	288	237	239	218	228	----------
Evaporation computed [1]	7.025	6.322	10.049	9.591	10,097	9.611	11.361	11.036	7.806	6.500	6.256	7.399	103.053

[1] From equation of Fitzgerald.

ST. CROIX, VIRGIN ISLANDS (1920–1930)

[Lat. 17° 46′ N., long. 64° 45′ W.]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Evaporation	4.779	5.005	6.535	7.202	7.241	6.909	7.249	7.098	6.141	5.731	4.550	4.537	72.977
Wind mileage	1,312	1,046	1,270	1,172	1,230	1,364	1,499	1,302	1,009	820	792	1,082	13.898
Rainfall	2.70	2.10	2.31	1.62	2.40	2.00	3.34	4.35	6.59	5.50	4.72	2.83	40.46
Mean temperature	75.9	75.4	76.0	77.6	79.6	80.9	81.4	81.6	81.1	79.9	78.2	76.6	78.7

KINGSTON, JAMAICA (1924–1930)

[Lat. 18° 1′ N., long. 76° 48′ W.]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Evaporation	5.463	4.997	7.020	7.987	7.920	7.289	8.121	7.911	5.457	4.377	3.757	4.324	74.623
Rainfall	0.37	0.69	0.42	0.94	1.78	0.63	1.14	4.39	3.30	6.00	3.25	0.99	23.90
Mean temperature	76.6	76.3	77.4	78.4	80.3	81.4	81.8	81.7	81.1	80.1	79.0	77.2	78.7

THE PIONEER METEOROLOGICAL WORK OF ELIAS LOOMIS AT WESTERN RESERVE COLLEGE, HUDSON, OHIO, 1837–1844

By ERIC R. MILLER

[Weather Bureau Office, Madison, Wis.]

In the spring of 1836 Elias Loomis (1811–1889), who had been a tutor at Yale, was appointed professor of mathematics and natural philosophy in Western Reserve College, one of the institutions acting as hosts for the meeting of the American Meteorological Society at Cleveland in 1930. Western Reserve College had been founded in 1826 at Hudson, Ohio, about 20 miles southeast of Cleveland, as a sort of Yale in Ohio by the Connecticut people who had first settled the region.

Loomis's salary was to be $600 per annum, but there was an economic depression in progress then as now, so that so much of his salary as was not paid in kind remained in arrears, and when he left Hudson the college offered to deed him some of its unimproved lands (**1**). He was allowed to spend the first year of his professorship in Europe, where he attended the lectures of Arago, Biot, Dulong, Poisson, and Pouillet in Paris, and bought apparatus there and in London, but did not have money enough to go to Germany. In the autumn of 1837 he returned to Hudson to teach and investigate for the next seven years. The chief objects of his researches were terrestrial magnetism, auroras, and storms.

Intense interest in storms had been aroused by the publications of Redfield, Espy, Dove, Reid, and Piddington, of whom Redfield and Espy had become involved in a hot controversy over the air circulation in tropical cyclones (**2**). To put the rival theories to the test of experiment, Loomis set about collecting all available data "on the storm which was experienced throughout the United States about the 20th of December, 1836," as the title of his paper runs (**3**). This storm was selected because it occurred within a period recommended by Sir John Herschel for hourly meteorological observations. The extent to which Americans were then cooperating in international meteorology is indicated by all of the phenomena having been recorded hourly at eight stations—Baltimore, New York, Albany, Flushing, New Haven, Gardiner, Montreal, and Quebec. Loomis obtained barometer readings from 27 stations, and other information from stations distributed over most of the country east of the Rocky Mountains, as well as from Bermuda, the West Indies, and from a ship on the Pacific coast.

He mapped this storm at 6-hour intervals, studying the pressure, temperature, wind direction and velocity, and precipitation. The center passed north of all of the observers, but he made a remarkable study of the phenomena of the cold front, of which his paper contains an isochronal map showing how it swept across the country. To illustrate the lines on which he attacked his problem, the following is quoted from this paper:

> But how is it possible for two winds not far separated from each other to blow violently toward each other for hours and even days in succession? Let us make a simple numerical estimate. The wind blew from the northwest at least 40 miles per hour. This gives a progress due east of more than 28 miles per hour, and is fully equal to the average progress of the barometric minimum. The atmospheric wave, then, progressed with not far from this velocity with which the wind was observed to blow, but in order to allow an opportunity for this onward progress, the wind in advance of the wave must retire, and that with the same velocity with which the northwest wave approaches. * * * The conclusion is inevitable that the northwest wind displaces the southeast wind by flowing under it. * * * The southeast current found its escape by ascending from the surface of the earth. Having quit the surface, it might either flow on in its first direction over the northwest current, or it might be driven back over the southeast current, or both of these motions might exist simultaneously. When we come to consider the cause of the rain, we shall be able to judge of the probability of these several suppositions.

After discussing radiation, advection, mixing, and "air suddenly transported into elevated regions" he observes that "the fourth cause of precipitation must be allowed to be by far the most efficient of all."

> Snow and hail (ice pellets?) did fall at nearly all of the northern stations after the northwest wind set in, but the amount was small, much less than must necessarily result if the entire southerly

wind had flowed over the northerly and had its moisture precipitated by it. Still, it seems probable that a part of the southerly wind did continue on its course and produce the snow which was observed to fall. I infer that the current was mainly turned back upon itself so that the moisture as fast as precipitated fell through the lower current still blowing from the southeast. My idea may best be illustrated by a diagram (p. 159).

The diagram anticipates with remarkable exactness the form of a cold current underrunning still, warm air, found experimentally by W. Schmidt (4).

A tornado in northeastern Ohio in February, 1842, started Loomis studying two storms of that month. His paper on these storms (5) created a great sensation at the centennial meeting of the American Philosophical Society in May, 1843, both on account of the light that it shed on the theories of Redfield and Espy, and still more by reason of his invention of the synoptic weather map with isobars and isotherms. He had no means of reducing the barometer to sea level so that he was obliged to draw isobars of equal departure from normal. His paper is illustrated with 13 of these maps, 7 showing the progress of the parent storm of the tornado from February 2 to 5, 1842, the other 6 show the storm of February 15–17, 1842, both at 12-hour intervals. Brandes at Leipzig had constructed similar maps in 1820 and 1826, but did not publish them. Loomis was apparently unaware of the work of Brandes, and is in any case entitled to the credit of first publication.

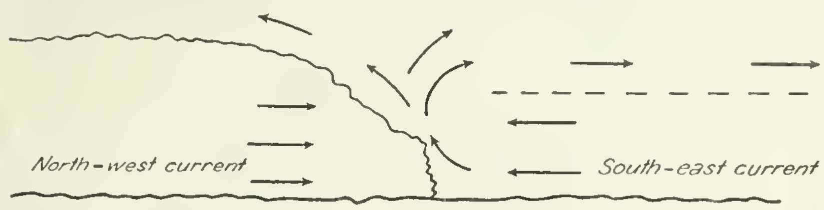
In this paper again, Loomis is concerned with the thermodynamics of ascending and descending air, and quotes the observations and experiments of Poisson, Gay-Lussac, Forbes, Pouillet, Leslie, and especially the experiment of Clement and Desormes which is still repeated by sophomores in the college course in physics to-day. The following quotation (p. 174) shows one of Loomis's applications of the theory:

As the westerly wind pours over the (Allegheny) mountains and descends to the level of the sea it comes under greater pressure, and heat is developed which dissolves the vapor, producing clear sky. Thus clear sky succeeds a storm much sooner on the eastern than on the western side of the mountains.

This paper also contains two anticipations of the Bjerknes Polar Front theory (p. 178). "These oscillations are propagated by the laws of waves." On page 180 he charts the instantaneous directions of the winds in two cyclones and shows that these consist of two streams of air, of which the northwest current revolves in an inflowing spiral around and impinges against the side of the southeast current.

Loomis numbered among his students at Western Reserve College an energetic fellow, Halbert E. Paine, who rose to be major general of Volunteers in the Civil War, was elected to Congress while yet in camp, and afterward was appointed Commissioner of Patents. In the second of these capacities Paine put through Congress in the record time of seven days the act that started our present national weather service.

Loomis went to the University of New York in 1844, where he wrote many of the textbooks that made him famous and wealthy. He succeeded Joseph Henry at Princeton when the latter became the first secretary of the Smithsonian Institution, but Loomis was induced to return to New York the following year and remained



until 1860 when his alma mater, Yale, called him to the professorship that he held the remainder of his life. His Treatise on Meteorology was published in 1868. Beginning 1874 he presented a series of 23 contributions to meteorology to the National Academy of Sciences.

Loomis's prestige was used by Henry to support the extensive meteorological program of the Smithsonian Institution when it was organized in 1847, and by Paine again in 1870 when the meteorological work was initiated under the chief signal officer of the Army, which has developed into the present United States Weather Bureau.

Loomis passed away in 1889 at the age of 78. His fortune of $300,000 derived from his text-books, left to Yale University, was the largest bequest received up to that time by that institution.

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GREAT DUST STORM IN WASHINGTON AND OREGON, APRIL 21–24, 1931 [1]

By Donald C. Cameron

[Weather Bureau Airport, Portland, Oreg.]

SYNOPSIS

A considerable part of Washington and Oregon experienced on April 21–24, 1931, an extraordinary dust storm borne on strong northeast winds that were common to both States, although of greater force in some parts than in others.

A week previous saw the end of a rather protracted wet spell in both States which was succeeded by clear skies very low relative humidity under which the top layers of the soil had dried out very thoroughly so that the strong northeast winds that occurred on the 21st whipped up great quantities of dust from the wheat country and the semiarid parts of the interior and carried westward and southward as a dust cloud of great magnitude that subsequently blew itself out over the Pacific Ocean. The strength of the wind was such as to overcome and blow down frail structures and even great trees. So high winds were quite exceptional for the time and place. Forest and brush fires broke out suddenly over much of the territory invaded by the dust storm; the very low relative humidity and poor visibility made fire suppression very difficult.

The winds subsided during the night of the 22d and 23d and during the daylight hours of the 23d but a smoke pall continued for several days in the territory affected.

The strong northeast winds were due to the presence of a large mass of cool dense air centered over the northern part of the Province of Alberta and especially to the relative position of this cool air mass with respect to one of higher temperature and less density than occupied the northern border States of Idaho, Montana, and the Great Basin. The isobaric chart, Figure 1 shows an isobar of 30.7 inches open to the northward, thus marking the

[1] Somewhat condensed from the original.—Ed.

southward extension of the denser air and as shown by the wind arrows an air movement toward the less dense air mass over the Great Basin has already set in. Normally there is a flow of air from regions of great air density to regions of less density. Figure 2 shows the isobaric situation 12 hours later than Figure 1 and it also

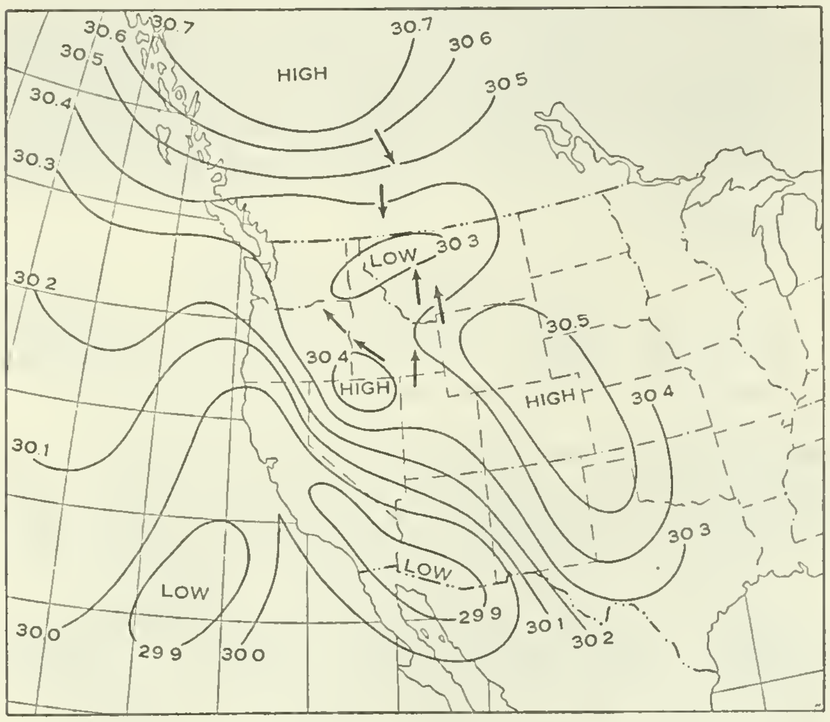


FIGURE 1.—Isobaric chart 5 a. m. 120th meridian time April 21, 1931

shows by the shaded area over Washington that the dust storm had already taken tangible form; the subsequent charts portray the regions of great dust intensity by solid shading.

The strength of the northeast winds during the 21st was augmented by a very pronounced fall in atmospheric

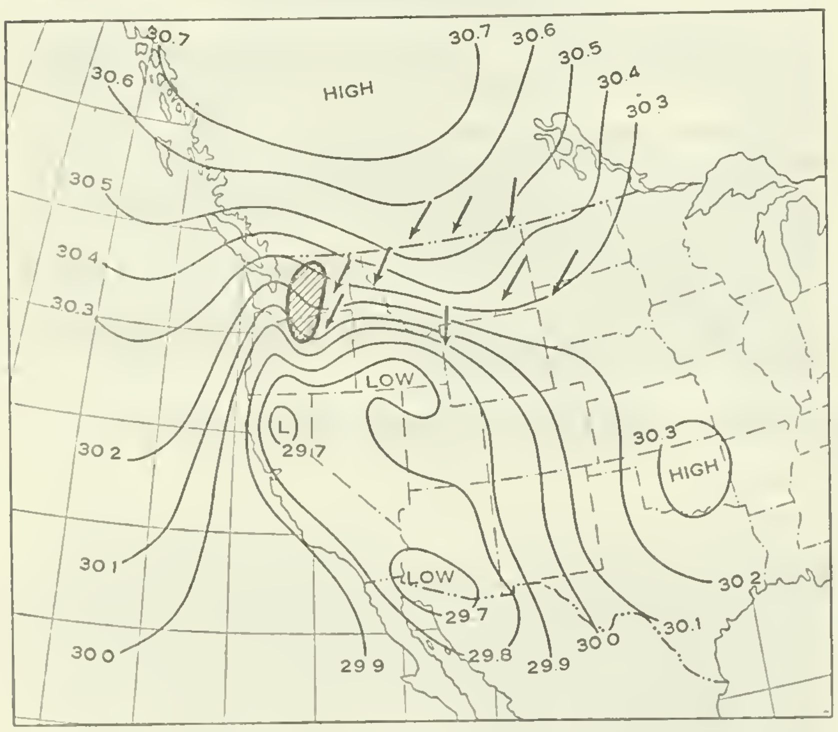


FIGURE 2.—Isobaric chart 5 p. m. 120th meridian time April 21, 1931. Shaded area shows position of duststorm and arrows wind direction

pressure over southwestern United States and up to Oregon and southern Idaho best shown by Figure 3 on which the difference in pressure between the cool, dense air in the northeast and the less dense over the Great Basin is 1.35 inches. This great difference in pressure supplied the energy of the northeast winds as manifested in the destruction of frail structures, the blowing down of great trees and uprooting of others as shown on the inset sheet. (Fig. 6.)

The next chart of the series, Figure 4, marks the end of the dust storm. The pressure level in the cool dense

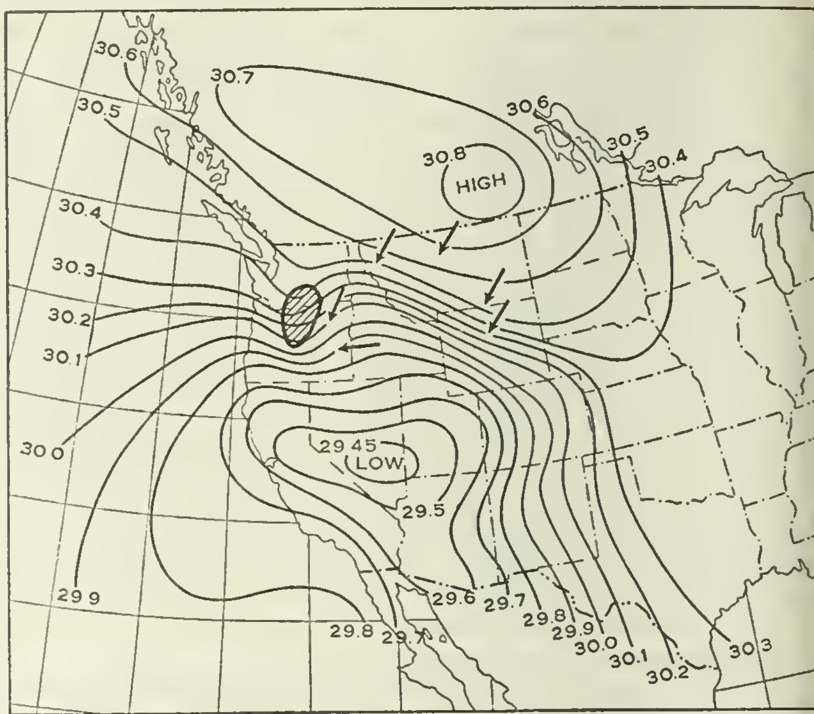


FIGURE 3.—Isobaric chart 5 a. m. 120th meridian time April 22, 1931. Wind direction by arrows and position of dust storm in solid shading

area has fallen four tenths of an inch and the pressure situation has drifted so far to the east and south as to no longer control the wind circulation in Washington and Oregon.

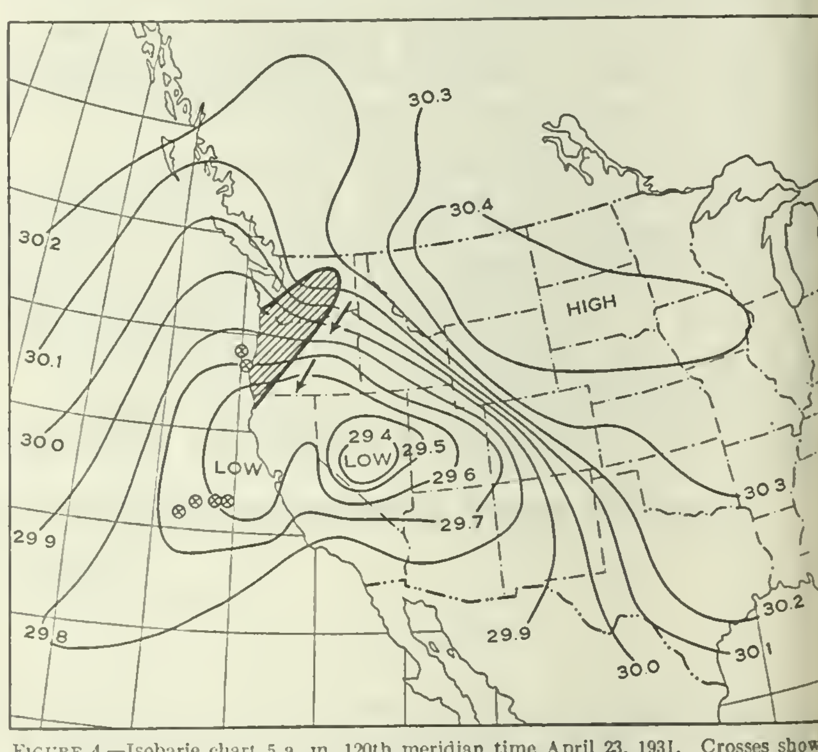


FIGURE 4.—Isobaric chart 5 a. m. 120th meridian time April 23, 1931. Crosses show approximate positions of vessels that observed dust storm; solid shading, position of dust storm; wind directions by arrows

The progress of the great dust front is graphically shown in Figure 5 based upon reports from airway and other stations.

The arrival overhead of the colder air at Pasco, Wash., was heralded by increasing cloudiness and light drizzling rain. At 2 p. m. Pasco's wind had become southeast, 15 m. p. h. but at Arlington in the northwestern part of the State the wind increased to *northeast strong* from *east*

FIGURE 6.—Wind destruction: Upper shows abandoned orchard trees uprooted by the northeast gales, lower, a mountain home and outbuilding crushed by heavy timber (near base of Mount Hood)

light and "sand storm" was reported.[2] At Umatilla on the Columbia River about 200 miles southeast of Arlington dust clouds were observed to the westward. Grand Dallas near to Dalles and close to the eastern entrance to the Columbia River Gorge reported dust clouds visible to the east. During this period (p. m. of 21st) the barometer was rising at Spokane, Pasco, and Walla Walla, clearly indicating the approach overhead of colder air; at the same time, however, an unusual fall in the barometer was taking place at Burns, Oreg., and Boise, Idaho (0.20 inch in 3 hours), thus tending to greatly increase the strength of the northeast winds.

The advancing northeast wind was a deep one, as evidenced by the pilot-balloon run at Spokane, Wash., at 3 p. m. when northeast gales were observed to the top of the run at about 5,000 feet; the great height was also evidenced by the experience of a Varney mail plane which left Pasco about 1 p. m. of the 22d climbed to the level of 14,500 feet in an effort to surmount the dust cloud. The pilot lost sight of the ground below and when he recovered his bearings the waters of the Pacific came into view near Seaside, Oreg., about 60 miles west of Portland. The strength of the tail wind had been underestimated by the pilot and his plane passed its destination.

The free-air winds above Paso, 3 p. m. of the 22d, were as follows:

At 700 feet 40 m. p. h.
At 1,400 feet 77 m. p. h.
At 2,000 feet 78 m. p. h.
At 2,600 feet 71 m. p. h.

Space does not permit the recital of the items of interest that were reported during the passage of the dust cloud from Tacoma on the north to Mount Shasta on the South. The continuation of the storm over the Pacific is described in the following.

THE DUST STORM CONTINUES OVER THE PACIFIC [3]

Five vessels navigating the Pacific near the west coast of the United States encountered the dust storm hereinbefore described on April 22, 23, and 24. The vessels have been listed and the remarks in reference to the storm are given in tabulated form following.

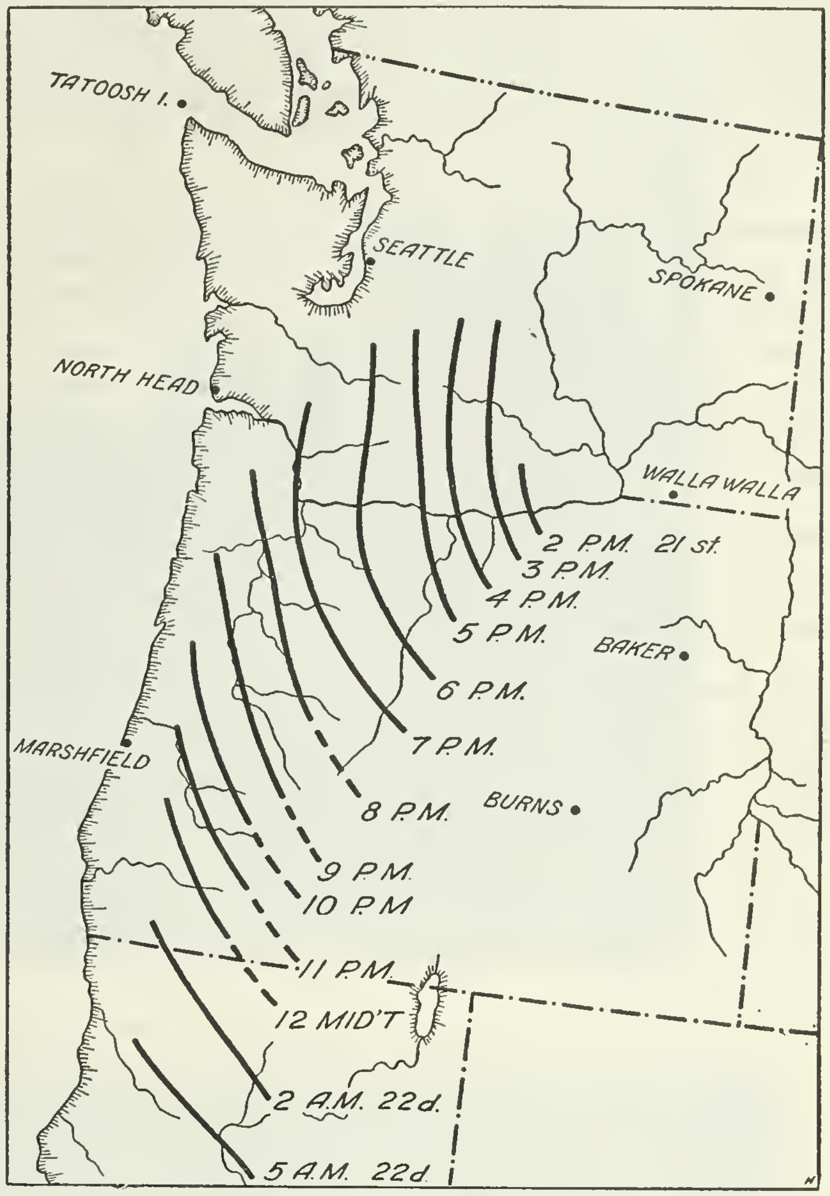


FIGURE 5.—Dust-storm fronts, hourly, as it passed over Washington, Oregon, and California

[2] Cf. Brooks, Chas. F. Warm, dry gale and dust storm in Northwest. Bulletin American Meteorological Society 12:112-13.
[3] Condensed from reports received by the Marine Division, U. S. Weather Bureau.

Vessels encountering dust storm in east Pacific

Name	Latitude	Longitude	Date and time	Wind direction and force	Remarks
	° ′	° ′			
Albertolite	44 06 N	125 00 W	22d	NE. 6	Visibility so low it necessitated navigating as in fog. At this time the atmosphere was filled with fine particles of dust or sand and there was a distinct odor of smoke.
Emma Alexander	43 31 N	124 46 W	22d	NE. 6	Ship ran into a heavy dust storm—dust covering entire ship and shutting off visibility to the extent that it was necessary to sound the whistle.
Mericos H. Whittier	36 45 N	125 47 W	22d	NW. 6	When first encountered it was considered a low fog bank; visibility was restricted to about 3 miles and the sky was perfectly clear. But when daylight arrived it was noticed that the ship had a coating of fine brown-colored dust all over. During the 23d the dust bank remained at practically the same consistency throughout the day having an altitude of about 30° but from 5 p. m. it was noticed to be getting thicker and visibility decreased to about 1½ miles. During the early morning of the 24th the wind backed to SSW. 2 the dust gradually thinning until at 8 a. m. the atmosphere was quite clear except for the haze caused by falling rain. The ship's position at this time was lat. 34° 30′ N., long. 131° 45′ W.
Somme	36 34 N	127 30 W	23d	W. 2	Found heavy coat of fine brown dust that looked like volcanic ash.
Maui	36 20 N	127 19 W	23d	NNW. 3	Apr. 23 at 5 a. m. lat. 36° 20′ N.; long. 127° 19′ W. until 9 p. m. same date in lat. 34° 46′ N.; long. 131° 37′ W. this vessel was in a heavy dust area, wind NNW. to N. Area extended over 240 miles in SW.-NE. direction.

TORNADO STRIKES SWIFTLY-MOVING TRAIN

By R. J. McClurg
[Weather Bureau, Moorhead, Minn.]

The crack train, Empire Builder, Seattle, Wash., to Chicago, Ill., May 27, 1931, was struck by a tornado nearly at a right angle as it was speeding at nearly a mile a minute about 5 miles east of Moorhead, Minn. The locomotive weighing 136 tons and the tender 94 tons, remained on the track. The engineer reports the cab windows as being torn out and that his goggles were blown away. Mr. McClurg's report follows.—Ed.

A destructive tornado passed over part of extreme western Minnesota May 27, 1931, beginning about 4:15 p. m. The funnel-shaped cloud was first seen by farmers in the north part of Kurtz township about 10 miles south-southeast of the Moorhead Weather Bureau Office. It traveled an east-northeasterly course from first observation, crossing the Great Northern Railway track one-half mile northwest of Ruthruff siding, where it wrecked "The Empire Builder" at about 4:30 p. m. No observer can be found that knows the exact time this storm struck the train. From this point onward it took a north-northeasterly course for about 40 miles, where it destroyed everything in its path when it touched the ground. At times it lifted from the ground for several miles, only to swoop down to the ground again and carry on its destructive work. It evidently blew itself out between Gary and Fertile, Minn. It seems to be impossible to find anyone who knows at what time it was last seen. But it must have been traveling very rapidly for everyone who saw it spoke about its rapid movement. The tornado never came nearer than 4 miles to the United States Weather Bureau station at Moorhead.

The morning weather map of May 27 shows that Moorhead lay in a trough of low pressure, the center of which was over southeastern South Dakota. At the Moorhead station the following atmospheric conditions were recorded:

The barograph showed the air pressure was very erratic from 1:30 a. m., with a reading of 28.74 inches, until 2:00 p. m. at which time the reading was 28.64 inches. The pressure then fell rapidly to 28.47 inches by 4:30 p. m., then remained almost constant to 5:15 p. m. It then rose rapidly until 5:30 p. m., after which the rise was more gradual. Light rain began to fall at 4:04 p. m. with a heavy downpour from 4:16 p. m. to 4:37 p. m. Soft hail fell with the rain for 6 minutes. The total precipitation was 0.31 inch. The sun shone intermittently from 4:41 for the remainder of the evening. The wind velocity was from 6 to 13 miles an hour from 4 p. m. to 5:16 p. m., and was recorded at least once from the eight points of the compass. From 5:12 p. m. a southwest wind was increasing steadily, when at 5:30 p. m. it suddenly shifted to the northwest and reached a velocity of 33 miles an hour for 5 minutes. One mile was recorded at the rate of 36 miles per hour. The wind decreased steadily after 5:35 p. m.

Despite the untold damage done by this tornado of gigantic power, the marvelous thing about it is that only two lives were lost. When one car of the famed "Empire Builder" with its 117 passengers was lifted from the rails and carried through the air to be laid in a ditch 80 feet away, one man was hurled through a window and crushed beneath the coach when it fell on him. The other death resulted when a farm youth was pinned beneath the wreckage of his home and crushed to death.

The greatest manifestation of the force of this storm was shown by the wrecking of the train. Without a doubt, five of the coaches were torn loose from the engine and lifted bodily from the rails, the farthest one being hurled 80 feet away. The remaining eight coaches were probably pulled from the rails. The engine and tender remained on the rails intact. Fifty-seven passengers were injured by the impact and flying glass. It was due only to the fact that the heavy steel coaches were strong enough to resist the crash that more lives were not lost.

According to available reports, only 3 houses, 1 church, and 1 schoolhouse were demolished. The remainder of the damage was to other farm buildings, machinery, livestock, and trees.

On a tour of a portion of the path of the tornado the writer observed the usual freakish actions of the storm. At the Hatledal farm where one of the deaths took place the family are positive that two separate storms occurred. The first twister coming from the southwest destroyed the home, pinning Melvin Hatledal beneath a cement block in the southeast corner of the basement. After this twister passed on, the family escaped from the basement to the yard. In just a few minutes they observed a second twister, yellowish in color, approaching from the northwest. They expected it to strike them any second, but it veered to the east just before it reached them and wrecked a barn about 250 yards distant.

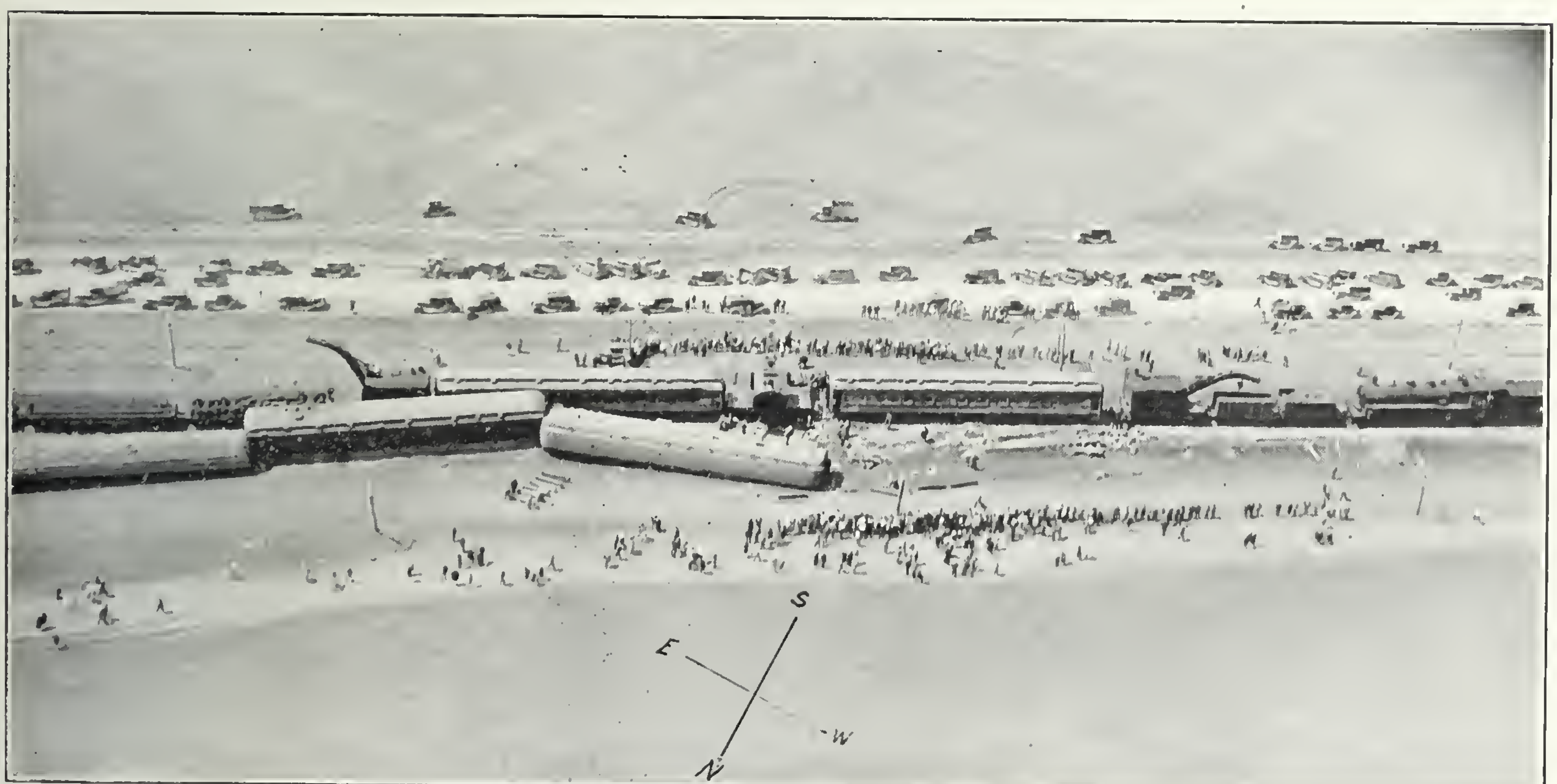
At the Fred Kudebeh farm a mile or so northwest of the Hatledal farm, Mr. Kudebeh was standing in his barn door watching the main twister passing about 200 yards to the east of him. All at once his own barn was lifted into the air leaving him standing unharmed. The barn was carried almost due west straight toward the farmhouse. One wall landed on the north side of the house, one wall on the south side, and one end on the east side of the house. The other end of the barn fell just a few feet west from the foundation. But the roof was carried over the house, through the tops of a grove of trees, some of which were 50 feet high, and fell in a field fully 200 yards from where the barn originally stood. Yet the house was not touched, except one corner of the porch which was struck by a flying timber.

The main twister traveling due north at the time struck the Hanson farm where absolutely everything was demolished. House, barns, machine sheds, farm implements, dead animals and poultry were scattered all over the countryside. Farm implements of heavy iron and steel were twisted beyond recognition. Thirteen almost featherless chickens remained from a flock of 300. Trees were denuded of their limbs and leaves. The wreckage was carried to the northwest, while at another farm only about 300 yards west, wreckage was carried to the southeast.

The writer saw straws driven into the bark of trees and at one place, saw a fresh straw driven in the wall of a house. At one place it was reported that a lace curtain was blown between the pane of glass and the sash with the glass remaining unbroken.

A conservative estimate of the damage was placed at $200,000. Growing crops not damaged very much where the storm did the damage to buildings, but reports from the higher lands to the southeast, where the soil is lighter, state that many fields will be reseeded because the wind blew away the planted crops.

The smaller picture of the two (fig. 1) was taken a few hours after the storm from the end of the fourth coach from the rear of the train. Eight coaches between the coach in the front of the picture and the engine in the background are lying in a ditch to the left of the picture. The aerial view was taken after the wrecker had placed two of the coaches back on the track.



Photos furnished through courtesy of Mr. Hooper, City Editor, Fargo Forum

FIGURE. 1.—Upper, taken from end of fourth coach from rear of train; eight coaches are lying in a ditch to the left; lower, an aerial view of the wrecked cars after the wrecker had put two cars back on track

SUPPLEMENTAL REPORT BY R. J. M'CLURG

I had a conversation with the engineer, Mr. McKee, and the fireman, Mr. Klinfihn, these men gave an account of their observation of the tornado.

Mr. Klinfihn observed the storm at a distance, but did not see the funnel cloud. At the time the train was struck, he was busy at his work firing and was completely unaware of the impending disaster.

Mr. McKee, the engineer, first noticed the storm a mile or so away in the southwest, but did not see a funnel at that time. The train was traveling toward the southeast. He had seen many worse looking storms and did not give it much attention at first. The storm did not seem to move at all for several minutes, then moved slowly toward the train until it was about one-half mile away. It was then he noticed the funnel cloud and saw it take the top off a straw stack. The twister then darted forward and before he realized it was coming it had struck the train at almost right angles.

Mr. McKee thought the full force of the storm struck the engine; but due to the immense weight of the engine and the round shape, the engine and loaded tender were left standing on the rails. The remainder of the train of 12 coaches was derailed. Mr. McKee's glasses were pulled from his face by a force that he described as "a suction at his body." The fact that the coupling between the engine and the mail car was unbroken and still closed and locked after the wreck indicates that the front end of the mail car was lifted directly upward, permitting the coupling to separate without breaking. All the 12 cars remained coupled to each other, but some of the couplings were badly twisted by the derailment. All but one of the cars fell on their sides. This one exception was a car caught between two coaches and could not fall over. On page 2 of my report of June 2, 1931, I stated that five coaches were lifted from the tracks and the other 8 were pulled from it. It should read "Five coaches were lifted from the tracks and the other 7 were pulled from the track."

The conductor stated that practically all of the windows of the coaches were closed because a light rain was falling; the car ventilators were open. The greater number of the windows were not broken by the sudden lessening of the outside pressure. They had to be broken by trainmen and others to let the imprisoned passengers escape.

The following is a list of the weights of the cars and engine:

	Tons		Tons
Engine	136	Diner	89
Tender, loaded	94	Pullman	64
Mail car	70	Do	64
Baggage car	72	Do	64
Smoking car	59	Do	64
Day coach	83	Do	61
Tourist	76	Club car	85

TABLE FOR FACILITATING COMPUTATION OF POTENTIAL TEMPERATURE

By J. C. BALLARD

[Aerological Division, Weather Bureau, Washington, D. C.]

The following table of factors has been found to be very useful in the computation of potential temperatures. Where P = pressure in millibars, the table gives values $K=\left(\frac{1000}{P}\right)^{0.288}$ for intervals of one millibar from 1,049 to 40 millibars of pressure. For lower pressure the computation must be made by logarithms.

The factor $\left(\frac{1000}{P}\right)^{0.288}$ is the pressure factor in the formula

$$\Theta = T\left(\frac{1000}{P}\right)^{0.288}$$

Where θ = potential temperature in °A, T = actual temperature in °A and P = pressure in millibars. Hence, it is evident that the potential temperature is computed merely by multiplying the actual temperature in °A by the proper factor (K) found in the table.

Computations have been made for whole millibars, and where pressure is used to tenths of millibars, linear interpolation for tenths has been found to be sufficiently accurate for ordinary purposes. Several cases have been tested for error in the factor due to linear interpolation and in no case has an error as much as 0.0003 been found. An error of 0.0003 in the factor would never produce an error of more than 0.1° in potential temperature, or one well within the range of accuracy of the observed temperature and pressure. The accompanying graph (fig. 1) is the curve $Y=\left(\frac{1000}{P}\right)^{0.288}$. It is apparent that for low pressures where differences in the values of the function are relatively great for small differences in pressure, the error due to interpolating linearly between two pressures for intermediate values of the function would be relatively small.

If it is desired, tables of interpolated parts can be prepared which will assist somewhat in the interpolation.[1]

[1] Such tables are available in Publication No. 245 of the Carnegie Institution, 1918, by H. B. Hedrick.

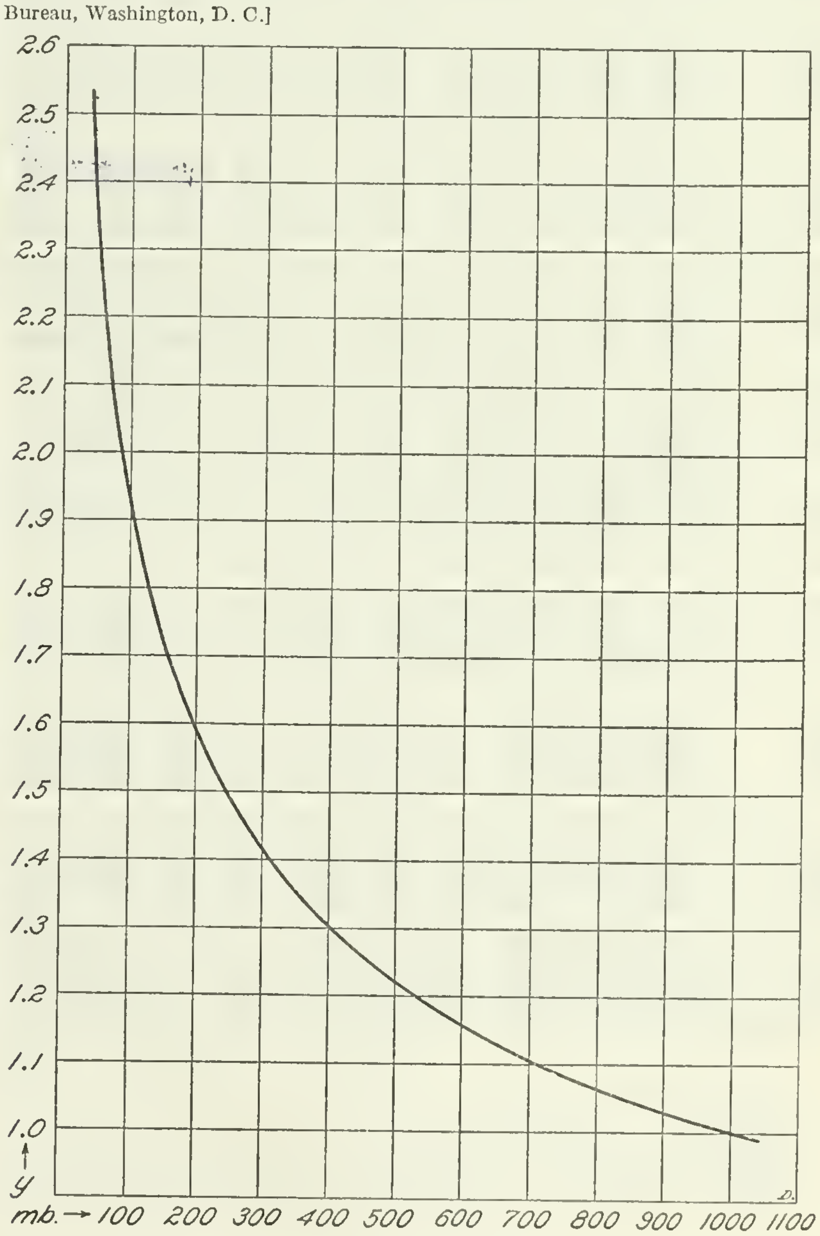


FIGURE 1.—Graph of the curve $Y=\left(\frac{1000}{P}\right)^{0.288}$

For rapid and approximate computation of potential temperatures it may be found convenient to prepare a large graph similar to Figure 1, by which approximate values of the pressure factor can be easily obtained. The Adiabatic Chart gives potential temperatures directly for any given temperature and pressure within a limited range, and a proper extention of this chart would make it possible to read off potential temperatures for any given temperature and pressure with no computation whatever.

The paper Tables of the 0.288 th. powers by Dr. T. N. Doerr of Vienna, published in the Quarterly Journal of the Royal Meteorological Society, Vol. 47, 1921, pages 196–202, was used in the preparation of the accompanying table. The values were obtained by dividing $(1000)^{0.288}$ by $(P)^{0.288}$ where P varied from 50 to 1,049, inclusive. The values for pressures from 40 to 49 millibars, inclusive, were computed by logarithms.

Potential temperature factor (K) for various pressures in mb.

[Temperatures in absolute degrees multiplied by K=potential temperatures]

Mb.	0	1	2	3	4	5	6	7	8	9
40	2.5270	2.5091	2.4917	2,4749	2,4586	2.4428	2.4273	2.4124	2.3977	2.3834
50	2.3697	2.3562	2.3431	2.3303	2.3178	2.3056	2.2936	2.2820	2.2706	2.2594
60	2.2485	2.2378	2.2274	2.2171	2.2071	2.1973	2.1876	2.1782	2.1689	2.1598
70	2.1509	2.1421	2.1335	2.1250	2.1167	2.1086	2.1005	2.0926	2.0849	2.0772
80	2.0697	2.0623	2.0550	2.0479	2.0408	2.0339	2.0271	2.0203	2.0137	2.0071
90	2.0007	1.9943	1.9880	1.9819	1.9758	1.9698	1.9638	1.9580	1.9522	1.9465
100	1.9409	1.9354	1.9298	1.9244	1.9191	1.9138	1.9086	1.9034	1.8983	1.8933
110	1.8883	1.8834	1.8786	1.8738	1.8690	1.8643	1.8597	1.8551	1.8505	1.8460
120	1.8416	1.8372	1.8328	1.8285	1.8243	1.8201	1.8159	1.8118	1.8077	1.8036
130	1.7996	1.7956	1.7917	1.7878	1.7840	1.7802	1.7764	1.7726	1.7689	1.7652
140	1.7616	1.7580	1.7545	1.7509	1.7474	1.7439	1.7405	1.7370	1.7336	1.7303
150	1.7270	1.7237	1.7204	1.7171	1.7139	1.7107	1.7076	1.7044	1.7013	1.6982
160	1.6952	1.6921	1.6891	1.6861	1.6831	1.6802	1.6773	1.6744	1.6715	1.6686
170	1.6658	1.6630	1.6602	1.6574	1.6547	1.6520	1.6493	1.6466	1.6439	1.6412
180	1.6386	1.6360	1.6334	1.6308	1.6283	1.6257	1.6232	1.6207	1.6182	1.6157
190	1.6133	1.6109	1.6085	1.6061	1.6037	1.6013	1.5989	1.5966	1.5943	1.5919
200	1.5896	1.5874	1.5851	1.5829	1.5806	1.5784	1.5762	1.5740	1.5718	1.5696
210	1.5675	1.5653	1.5632	1.5611	1.5590	1.5569	1.5548	1.5527	1.5507	1.5487
220	1.5466	1.5446	1.5426	1.5406	1.5386	1.5367	1.5347	1.5327	1.5307	1.5288
230	1.5269	1.5250	1.5231	1.5212	1.5194	1.5175	1.5157	1.5138	1.5120	1.5102
240	1.5083	1.5065	1.5047	1.5029	1.5012	1.4994	1.4977	1.4959	1.4942	1.4924
250	1.4907	1.4890	1.4873	1.4856	1.4839	1.4822	1.4805	1.4789	1.4773	1.4756
260	1.4740	1.4724	1.4707	1.4691	1.4675	1.4659	1.4643	1.4627	1.4612	1.4596
270	1.4580	1.4564	1.4549	1.4534	1.4519	1.4504	1.4488	1.4473	1.4458	1.4443
280	1.4428	1.4414	1.4399	1.4384	1.4369	1.4355	1.4340	1.4326	1.4312	1.4298
290	1.4283	1.4269	1.4255	1.4241	1.4227	1.4213	1.4199	1.4186	1.4172	1.4158
300	1.4144	1.4130	1.4117	1.4104	1.4091	1.4077	1.4064	1.4051	1.4038	1.4025
310	1.4012	1.3999	1.3986	1.3973	1.3960	1.3947	1.3934	1.3921	1.3909	1.3897
320	1.3884	1.3871	1.3859	1.3847	1.3835	1.3822	1.3810	1.3798	1.3786	1.3774
330	1.3762	1.3750	1.3738	1.3726	1.3714	1.3702	1.3690	1.3678	1.3667	1.3655
340	1.3644	1.3632	1.3621	1.3609	1.3598	1.3586	1.3575	1.3564	1.3553	1.3541
350	1.3530	1.3519	1.3508	1.3497	1.3486	1.3475	1.3464	1.3453	1.3443	1.3432
360	1.3421	1.3410	1.3400	1.3389	1.3378	1.3367	1.3357	1.3346	1.3336	1.3325
370	1.3315	1.3305	1.3295	1.3284	1.3274	1.3264	1.3254	1.3244	1.3234	1.3224
380	1.3214	1.3204	1.3194	1.3184	1.3174	1.3164	1.3154	1.3144	1.3135	1.3125
390	1.3115	1.3105	1.3096	1.3086	1.3077	1.3067	1.3058	1.3048	1.3039	1.3029
400	1.3020	1.3010	1.3001	1.2992	1.2983	1.2973	1.2964	1.2955	1.2946	1.2937
410	1.2928	1.2919	1.2909	1.2900	1.2892	1.2883	1.2874	1.2865	1.2856	1.2847
420	1.2838	1.2829	1.2821	1.2812	1.2803	1.2794	1.2786	1.2777	1.2769	1.2760
430	1.2751	1.2743	1.2735	1.2726	1.2717	1.2709	1.2701	1.2692	1.2684	1.2675
440	1.2667	1.2659	1.2651	1.2642	1.2634	1.2626	1.2618	1.2610	1.2602	1.2594
450	1.2586	1.2578	1.2570	1.2562	1.2554	1.2546	1.2538	1.2530	1.2522	1.2514
460	1.2506	1.2498	1.2491	1.2483	1.2475	1.2467	1.2460	1.2452	1.2444	1.2436
470	1.2429	1.2421	1.2414	1.2406	1.2399	1.2391	1.2384	1.2376	1.2369	1.2361
480	1.2354	1.2346	1.2339	1.2331	1.2324	1.2317	1.2310	1.2302	1.2295	1.2288
490	1.2281	1.2273	1.2266	1.2259	1.2252	1.2245	1.2238	1.2231	1.2224	1.2216
500	1.2209	1.2202	1.2195	1.2188	1.2181	1.2174	1.2168	1.2161	1.2154	1.2147
510	1.2140	1.2133	1.2127	1.2120	1.2113	1.2106	1.2099	1.2093	1.2086	1.2079
520	1.2072	1.2066	1.2059	1.2052	1.2045	1.2039	1.2032	1.2026	1.2019	1.2013
530	1.2006	1.2000	1.1993	1.1987	1.1980	1.1974	1.1967	1.1961	1.1955	1.1948
540	1.1942	1.1935	1.1929	1.1923	1.1917	1.1910	1.1904	1.1898	1.1891	1.1885
550	1.1879	1.1872	1.1866	1.1860	1.1854	1.1848	1.1842	1.1836	1.1830	1.1823
560	1.1817	1.1811	1.1805	1.1799	1.1793	1.1787	1.1781	1.1775	1.1769	1.1763
570	1.1757	1.1751	1.1745	1.1739	1.1734	1.1728	1.1722	1.1716	1.1710	1.1704
580	1.1699	1.1693	1.1687	1.1681	1.1675	1.1669	1.1664	1.1658	1.1653	1.1647
590	1.1641	1.1635	1.1630	1.1624	1.1618	1.1613	1.1607	1.1602	1.1596	1.1591

Potential temperature factor (K) for various pressures in mb.—Contd.

Mb.	0	1	2	3	4	5	6	7	8	9
600	1.1585	1.1579	1.1574	1.1568	1.1563	1.1557	1.1552	1.1546	1.1541	1.1535
610	1.1530	1.1524	1.1519	1.1513	1.1508	1.1502	1.1497	1.1492	1.1487	1.1482
620	1.1476	1.1471	1.1465	1.1460	1.1455	1.1449	1.1444	1.1439	1.1434	1.1428
630	1.1423	1.1418	1.1413	1.1408	1.1403	1.1398	1.1393	1.1387	1.1382	1.1377
640	1.1372	1.1366	1.1361	1.1356	1.1351	1.1346	1.1341	1.1336	1.1331	1.1326
650	1.1321	1.1316	1.1311	1.1306	1.1301	1.1296	1.1291	1.1286	1.1281	1.1276
660	1.1271	1.1266	1.1261	1.1256	1.1252	1.1247	1.1242	1.1237	1.1232	1.1228
670	1.1223	1.1218	1.1213	1.1208	1.1203	1.1198	1.1194	1.1189	1.1184	1.1180
680	1.1175	1.1170	1.1165	1.1160	1.1156	1.1151	1.1146	1.1142	1.1137	1.1133
690	1.1128	1.1123	1.1118	1.1114	1.1109	1.1105	1.1100	1.1096	1.1091	1.1087
700	1.1082	1.1078	1.1073	1.1069	1.1064	1.1060	1.1055	1.1051	1.1046	1.1042
710	1.1037	1.1033	1.1028	1.1023	1.1019	1.1014	1.1010	1.1005	1.1001	1.0996
720	1.0992	1.0988	1.0983	1.0979	1.0975	1.0970	1.0966	1.0962	1.0957	1.0953
730	1.0949	1.0944	1.0940	1.0935	1.0931	1.0927	1.0923	1.0918	1.0914	1.0910
740	1.0906	1.0901	1.0897	1.0893	1.0889	1.0884	1.0880	1.0876	1.0872	1.0868
750	1.0864	1.0859	1.0855	1.0851	1.0847	1.0843	1.0839	1.0834	1.0830	1.0826
760	1.0822	1.0818	1.0814	1.0810	1.0806	1.0802	1.0798	1.0794	1.0790	1.0786
770	1.0782	1.0778	1.0774	1.0770	1.0766	1.0762	1.0758	1.0754	1.0750	1.0746
780	1.0742	1.0738	1.0734	1.0730	1.0726	1.0722	1.0718	1.0714	1.0710	1.0706
790	1.0702	1.0698	1.0695	1.0691	1.0687	1.0683	1.0679	1.0675	1.0671	1.0668
800	1.0664	1.0660	1.0656	1.0652	1.0648	1.0644	1.0641	1.0637	1.0633	1.0629
810	1.0626	1.0622	1.0618	1.0615	1.0611	1.0607	1.0603	1.0599	1.0596	1.0592
820	1.0588	1.0584	1.0581	1.0577	1.0573	1.0570	1.0566	1.0563	1.0559	1.0555
830	1.0551	1.0548	1.0544	1.0541	1.0537	1.0533	1.0529	1.0526	1.0522	1.0519
840	1.0515	1.0512	1.0508	1.0505	1.0501	1.0497	1.0493	1.0490	1.0486	1.0483
850	1.0479	1.0476	1.0472	1.0469	1.0465	1.0462	1.0458	1.0455	1.0451	1.0448
860	1.0444	1.0441	1.0437	1.0433	1.0430	1.0427	1.0423	1.0420	1.0416	1.0413
870	1.0409	1.0406	1.0402	1.0399	1.0396	1.0392	1.0389	1.0385	1.0382	1.0378
880	1.0375	1.0372	1.0368	1.0365	1.0362	1.0358	1.0355	1.0351	1.0348	1.0344
890	1.0341	1.0338	1.0334	1.0331	1.0327	1.0324	1.0321	1.0318	1.0315	1.0311
900	1.0308	1.0305	1.0302	1.0298	1.0295	1.0292	1.0288	1.0285	1.0282	1.0279
910	1.0275	1.0272	1.0269	1.0266	1.0262	1.0259	1.0256	1.0253	1.0249	1.0246
920	1.0243	1.0240	1.0236	1.0233	1.0230	1.0227	1.0224	1.0221	1.0218	1.0214
930	1.0211	1.0208	1.0205	1.0202	1.0198	1.0195	1.0192	1.0189	1.0186	1.0183
940	1.0180	1.0177	1.0173	1.0170	1.0167	1.0164	1.0161	1.0158	1.0155	1.0152
950	1.0149	1.0146	1.0143	1.0140	1.0137	1.0133	1.0130	1.0127	1.0124	1.0121
960	1.0118	1.0115	1.0112	1.0109	1.0106	1.0103	1.0100	1.0097	1.0094	1.0091
970	1.0088	1.0085	1.0082	1.0079	1.0076	1.0073	1.0070	1.0067	1.0064	1.0061
980	1.0058	1.0055	1.0052	1.0049	1.0047	1.0044	1.0041	1.0038	1.0035	1.0032
990	1.0029	1.0026	1.0023	1.0020	1.0017	1.0014	1.0012	1.0009	1.0006	1.0003
1000	1.0000	0.9997	0.9994	0.9991	0.9989	0.9986	0.9983	0.9980	0.9977	0.9974
1010	0.9971	0.9969	0.9966	0.9963	0.9960	0.9957	0.9954	0.9952	0.9949	0.9946
1020	0.9943	0.9940	0.9938	0.9935	0.9932	0.9929	0.9926	0.9924	0.9921	0.9918
1030	0.9915	0.9912	0.9910	0.9907	0.9904	0.9901	0.9899	0.9896	0.9893	0.9890
1040	0.9888	0.9885	0.9882	0.9879	0.9877	0.9874	0.9871	0.9869	0.9866	0.9863

RECOVERY OF SOUNDING-BALLOON METEOROGRAPH AFTER THREE YEARS AND THREE MONTHS

By L. T. SAMUELS

What is believed to be a long-period record for the return of a balloon meteorograph occurred recently when a Fergusson meteorograph which was sent up from the Weather Bureau office, Los Angeles, Calif., on December 31, 1927, at 4:58 a. m. and found on April 12, 1931, approximately 125 miles to the southeast. The official in charge at Los Angeles reports, "The meteorograph was nearly covered with trash and the basket in which the meteorograph was tied when released was not found. The remains of the balloon were near the spot where the instrument was lying. The instructions that were tied to the instrument were still with it but they were only partly legible."

It was found that the smoked record was entirely legible and the computation of the ascent and descent are in strikingly close agreement. The record indicates a maximum altitude of 14,196 meters, although the stratosphere was not reached. The temperature decreased from 11.1° C. at the surface to −74.1° C. at the maximum altitude.

TEN YEARS OF SCIENTIFIC AIRPLANE ASCENTS IN HOLLAND

By Dr. H. G. CANNEGIETER

[Published in Zeitschrift für Angewandte Meteorologie. Das Wetter, Heft 10, Oktober, 1930. Abstracted by J. C. Ballard, Aerological Division, Weather Bureau, Washington, D. C.]

Ten years of upper-air observations by airplanes were completed at Soesterberg, Holland, in 1929, and eight years of similar observations at De Kooij, Holland. A

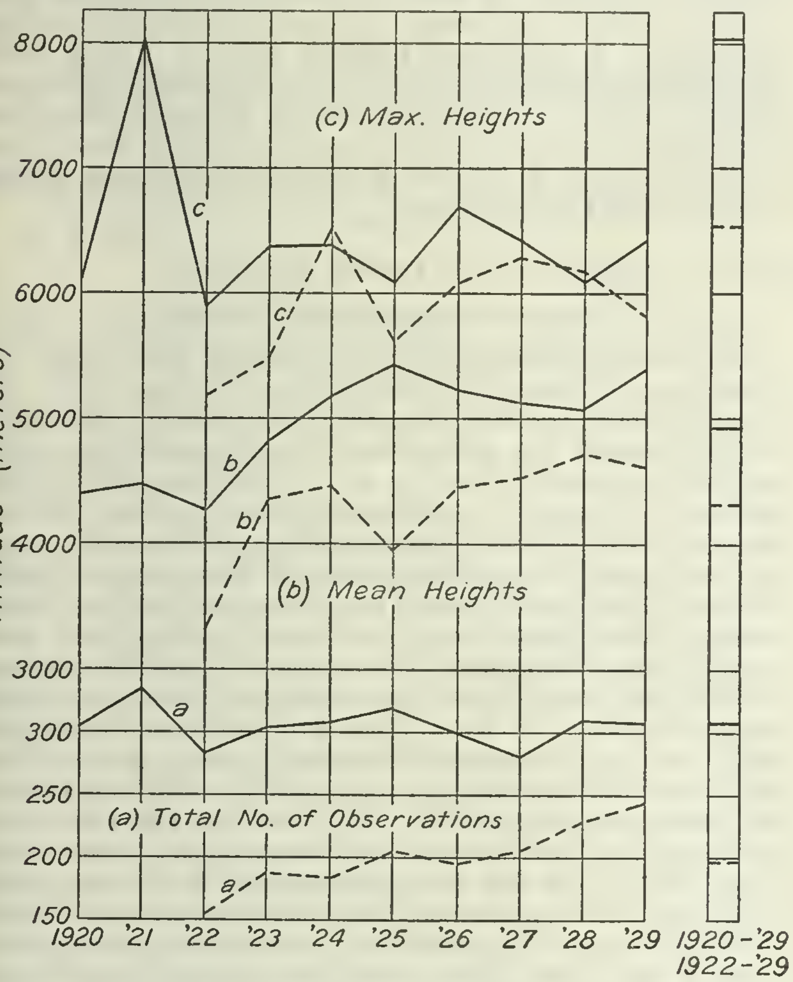


FIGURE 1.—Graph showing the total number of observations per year at Soesterberg, and the mean altitude attained

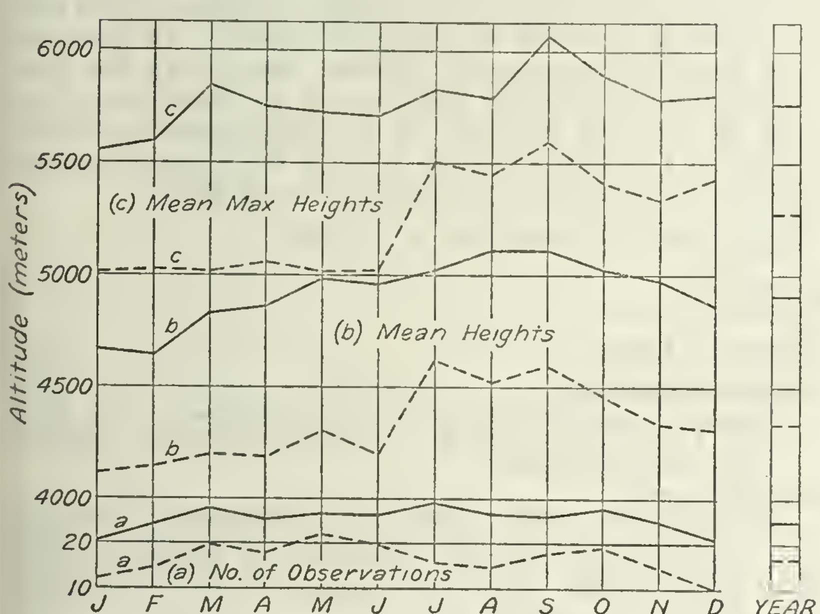


FIGURE 2.—Meteorological airplane observations in Holland: Solid line, Soesterberg, 1920–1929; dashed line, De Kooij, 1922–1929

good summary of the regularity of this service is shown by the accompanying charts.

It will be noted (fig. 1) that at Soesterberg the total number of observations per year averaged over 300 for the 10-year period and the mean altitude attained was nearly 5 km.

Figure 2 shows the monthly distribution. The least number of observations per month occurred in December and January, but at Soesterberg the average number of observations during these months did not fall below 20.

From 75 to 80 per cent of the observations were made before 10 a. m. and the remainder at later times during the day.

Note by abstractor.—It is interesting to compare these results with those obtained by kites and captive balloons in the United States. The average number of days per year (294) of kite and captive balloon observations at the five aerological stations of the Weather Bureau compares very favorably with these results. However, the mean altitude attained at these stations over the 9 year period 1922–1930, inclusive, is less than 2,700 meters above sea level.

S. HANZLIK ON ATMOSPHERIC PRESSURE EFFECT OF THE SUN-SPOT PERIOD

[Reprinted from Science Abstracts No. 754]

Part I. Yearly Means. S. Hanzlik. Gerlands Beitr. z. Geophys. 28. 1–3. pp. 114–125, 1930.—The difference of mean air pressure for the three years of sun-spot minimum and the succeeding three years of sun-spot maximum for stations over the whole globe is set out in a chart for each of the last five sun-spot periods, 1866–1919. Four different areas are indicated according to the sign of the effect. Areas of positive effect lie in the Indian monsoon region, pressure decreasing with increase of sun spots and vice versa. The fluctuations of this positive effect show a long period and a shorter one equal to two sun-spot periods (Hale's period). Over belts in middle latitudes and the Arctic regions Hale's period is shown but it is positive in middle latitudes when negative in the Arctic and vice versa. In South America there is a longer period but in a sense opposite to that in the Indian monsoon region. R. S. R.

SWEDISH-NORWEGIAN NORTHEASTLAND EXPEDITION

By LEONARD R. SCHNEIDER

During the summer of 1931, Hans W:son Ahlmann, professor of geography at the University of Stockholm, will lead a party of scientists to the little known region on and about Northeastland. Professor Ahlmann's party will board the *Quest* on or about June 15 at Narvik, Norway, and after a call at Spitzbergen to take on board supplies and a dog team, a stop will be made in Hinlopen Strait where, on Northeastland, supplies will be unloaded and a base camp constructed. Immediately upon the establishment of the base camp the members of the expedition will begin a summer of intensive study.

Two groups, one to study on the land, and one to carry on investigations in the nearby seas will conduct the major activities. Briefly, the land party will have as its work the following: (1) Meteorologists at the base camp will report their observations by radio to the *Quest* and to Sweden and Norway, (2) Professor Ahlmann and two assistants will go onto the inland ice for a month's study, and (3) geologists under O. Kulling and L. Rosenbaum, a topographer, will concentrate their efforts along Hinlopen Strait.

The investigations on board the *Quest* will be limited to the waters in the vicinity of Spitzbergen. The work of gathering sea-water temperatures, sea-water samples and of measuring depths, will be directed by H. Mosby of the Geofysical Institut, Bergen.

In concluding this summary of the projected work of the expedition it may be of interest to point out that the winter 1930–31 on Spitzbergen was unusually mild. In fact, at the end of March there was no ice in the expansive Icefjord and none on the sea in the immediate coastal region.

UPWELLING COLD WATER ON THE COAST OF NEW JERSEY

By CHARLES F. BROOKS

[Clark University, Worcester, Mass.]

On Sunday, July 7, 1929, while people were sweltering in New York City, others who had sought the Jersey coast were actually wearing coats. Mr. Henry B. Newhall reports that a friend of his, who has a summer home at Manasquan, was fishing in a lined fishing or hunting coat and was glad to have it on, but, he said that only a few thousand feet away from the shore it was pretty hot. They had had a strong S. to SE. wind for two or three days. The water, as somebody told him, as reported by the coast guards, was at unbelievably low temperatures—in the 40s.

In response to a request for the official temperatures, Assistant Commandant B. S. Chiswell, supplied the sea temperature readings for the first 15 days in July at Manasquan, N. J. They run as follows, beginning with the 1st; 47, 48, 52, 50, 48, 47, 46 (on the 7th), 50, 55, 60, 64, 68, 68, 70, 70 degrees. The sea temperature at Atlantic City from July 1 to 11, inclusive, as reported by Walcott L. Day, meteorologist, United States Weather Bureau, ranged from 62° to 67° and was 64° F. on the 7th. Atlantic City air temperatures that day ranged from 67° to 76° and on the preceding day 68° to 76° F. Winds on the 7th were S. to SW., 17 to 29 miles an hour. The wind on the 6th was of the same direction but averaged 16.4. Rather strong southerly winds prevailed also on the 4th and 5th, with average velocities of 18 and 20 miles an hour and maxima of 29 and 30, and an extreme 5-minute velocity of 32 miles.

On this occasion the S. to SW. winds which were onshore for Atlantic City were off-shore for the coast of New Jersey farther north. The tendency of wind to blow water in the direction 45 degrees to the right of its own direction in the northern hemisphere would favor a rapid removal of surface waters eastward and the consequent upwelling along the coast.

In the MONTHLY WEATHER REVIEW for June, July, and August, 1920 (48: 352–353, 424, 477–478), there are notes on a similar occurrence, attending a usual frequency of off-shore winds that summer.

G. T. WALKER ON SEASONAL FORESHADOWING

[Reprinted from Science Abstracts No. 757]

Roy. Meteorolog. Soc., J. 56, pp. 359–362; Disc., 362–364, October, 1930.—The paper contains results obtained by the author and E. W. Bliss in applying various relationships in different parts of the world to predict abnormal seasons. The application has been made for: (1) Summer monsoon rainfall in Australia which gave 24 successes of excess or deficit in 28 years, 2 failures and 2 years normal; (2) South African rainfall; (3) winter temperature in southwest Canada, and (4) winter temperature in northwest Canada. It is considered unwise at present to issue a prediction except in years when the indications of excess or defect are so strongly marked as to give a chance of success of 4:1 or 5:1 and this occurs in only about half the years.

R. S. R.

ICE IN THE ARCTIC SEA, 1930 [1]

[Report of the Danish Meteorological Institute]

The Danish Meteorological Institute has issued its report on the State of the Ice in the Artic Seas, 1930. In European Arctic waters there was extraordinarily little ice. In the Barents Sea and around Spitsbergen open water was more extensive than in any other year during this century. So early as February, the ice edge in the Barents Sea was in the normal position of May and June, and by August it was lying north of the western islands of Franz Josef Land instead of some three degrees to the south. Bear Island was free from ice by April, and remained free throughout the summer. From the autumn of 1929 until April, 1930, the whole west coast of Spitsbergen was clear of ice. After a little ice in May and June, the coast was again completely clear, and in July and August, the ice edge lay in lat. 81° N. During August the entire archipelago was free from ice, and there was practically no ice between Spitsbergen and Franz Josef Land. The Kara Sea was clear enough to be navigable in August and September. On the east coast of Greenland the ice was fairly abundant until the autumn, when parts of the coast were easily accessible. Iceland was almost ice free throughout the year. In Davis Strait the amount of ice was below the normal. Hudson Strait and Bay were clear of ice in July and August. In contrast with these comparatively ice-free coasts, Alaska and eastern Siberia had the pack ice up to their coasts for most of July and August. In fact, the polar ice would appear to have been driven against these coasts rather than out into the Barents and Greenland Seas.

[1] Reprinted from Nature, London, May 30, 1931, p. 834.

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING MAY, 1931

By Herbert H. Kimball, In Charge Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, Review, page 41.

Table 1 shows that solar radiation intensities averaged above the normal intensities for May at Washington, and below the May normals at Madison and Lincoln.

Table 2 shows an excess in the total radiation received on a horizontal surface as compared with the normal amount for May at Lincoln, close to normal at Pittsburgh and Fresno, and a deficiency at all other stations for which normals have been computed.

Skylight polarization measurements obtained on 9 days at Madison, gave a mean of 53 per cent with a maximum of 60 per cent on the 25th. At Washington, measurements obtained on three days give a mean of 56 per cent, with a maximum of 58 per cent on the 27th. These are close to the corresponding May averages for Washington. At Madison, the values were slightly below the corresponding averages.

Table 1.—*Solar radiation intensities during May, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 4	4.75	0.68	0.75	0.94	1.12	1.49	1.05				4.57
May 9	9.47				1.03	1.29					8.48
May 22	7.57		0.51	0.65	0.92						7.87
May 27	7.04	0.66	0.79	0.95	1.18	1.31	1.05				6.50
May 28	9.14	0.61	0.74	0.88	1.05	1.28	0.94				8.81
Means		0.65	0.70	0.86	1.06	1.34	1.01				
Departures		+0.01	−0.01	+0.04	+0.07	+0.05	+0.02				

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
May 1	3.81			0.73	1.00						4.37
May 2	4.75				1.01						5.16
May 4	2.36			0.77	0.98	1.34	0.95				4.17
May 5	5.16				1.04						5.16
May 13	7.04		0.78	0.91	1.11	1.46					6.76
May 15	7.04					1.34	1.08				7.04
May 23	5.79	0.69	0.79	0.94	1.14	1.40					5.16
May 25	8.18	0.72	0.85	0.98	1.15	1.44					7.29
May 26	7.29				0.93						9.14
Means		(0.70)	0.81	0.87	1.04	1.40	(1.02)				
Departures		−0.07	−0.06	−0.06	−0.06	+0.04	−0.01				

Table 1.—*Solar radiation intensities during May, 1931*—Contd.

[Gram-calories per minute per square centimeter of normal surface]

Lincoln, Nebr.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 2	4.37					1.40	1.13	0.93	0.78	0.66	4.57
May 3	4.57	0.57	0.69	0.83	1.03	1.45					4.75
May 14	7.29			0.89	1.17	1.38	1.16	0.95	0.80	0.69	7.57
May 15	7.87	0.68	0.77	0.91	1.12	1.36					9.47
May 20	3.81		0.87	1.01	1.19	1.42					3.81
May 22	5.16		0.82	0.97	1.10						5.79
May 23	11.81						1.04				6.50
May 25	8.81		0.43	0.64	0.87	1.19	0.86	0.64	0.48		10.21
Means		(0.62)	0.72	0.88	1.08	1.37	1.05	0.84	0.69	(0.68)	
Departures		−0.06	−0.08	−0.05	−0.04	−0.01	−0.06	−0.09	−0.10	±0.00	

[1] Extrapolated.

Table 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning	Average daily totals											
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 30	504	534	553	434	437	488	479	523	653	302	208	291
May 7	339	276	344	210	213	721	314	601	595	368	572	393
May 14	441	392	549	388	407	653	433	659	708	403	617	327
May 21	479	516	653	488	221	623	456	621	663	431	633	393
May 28	546	412	557	385	415	596	451	566	685	416	596	440
	Departures from weekly normals											
Apr. 30	+46	+77	+79	+69	+71	−81	+63	−82	+29	−105		
May 7	−116	−179	−136	−164	−149	+107	−94	−52	−48	−60		
May 14	−18	−72	+39	+8	+47	−1	+35	−7	+48	−30		
May 21	−9	+30	+121	+82	−159	−55	+12	−10	−27	−18		
May 28	+35	−79	+32	−38	+15	−87	−3	−30	−19	−46		
Accumulated departures on June 3, 1931	+145	−3,682	+266	−889	−679	+1,044	−423	−506	+119	−2,576		

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	h	m	°	°	°			
May 1 (Naval Observatory)	11	21	+60.0	273.2	+15.0	------	46	46
May 2 (Naval Observatory)	14	10	+72.0	270.5	+18.0	46	------	46
May 3 (Naval Observatory)	11	18	−52.0	134.8	+27.0	3	------	------
			−38.0	148.8	+2.0	19	------	22
May 4 (Naval Observatory)	11	16	+60.5	234.1	−10.0	------	46	46
May 5 (Naval Observatory)	10	52	−7.5	153.1	+10.5	22	------	22
May 6 (Naval Observatory)	10	49	−17.0	130.4	−2.0	3	------	------
			+9.0	156.4	+11.0	31	------	34
May 7 (Naval Observatory)	13	16	−70.0	62.9	+5.0	------	123	------
			+22.0	154.9	+13.0	15	------	138
May 8 (Naval Observatory)	10	48	−61.0	60.0	+5.0	------	108	------
			−49.0	72.0	+2.0	6	------	114
May 9 (Naval Observatory)	10	59	−50.0	57.7	+7.5	------	185	185
May 10 (Naval Observatory)	10	59	−37.5	57.0	+9.0	------	216	------
			−1.0	93.5	+34.0	9	------	------
			+40.0	134.5	+1.5	------	123	348
May 11 (Naval Observatory)	11	27	−21.0	60.0	+8.5	------	154	------
			+55.0	136.0	+1.5	------	77	231
May 12 (Mount Wilson)	11	30	−8.0	59.7	+9.0	------	121	------
			−7.0	60.7	+7.0	133	------	------
			+41.0	108.7	+5.0	------	5	------
			+71.0	138.7	−1.0	161	------	420
May 13 (Mount Wilson)	9	40	+4.0	59.4	+8.0	------	99	------
			+4.0	59.4	+7.0	124	------	------
			+55.0	110.4	+5.0	------	6	------
			+87.0	142.4	+0.5	51	------	280
May 14 (Naval Observatory)	11	5	+20.0	61.5	+10.0	------	139	139
May 15 (Naval Observatory)	12	22	−71.0	316.6	+8.5	31	------	------
			−60.0	327.6	−17.5	31	------	------
			−13.0	14.6	−6.0	3	------	------
			+34.0	61.6	+10.5	------	216	281
May 16 (Naval Observatory)	10	45	−65.0	310.2	+11.0	------	6	------
			−50.0	325.2	−17.5	------	170	------
			−2.5	12.7	+11.0	3	------	------
			+47.0	62.2	+10.5	------	185	364

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	h	m	°	°	°			
May 17 (Naval Observatory)	10	55	−60.5	301.4	+15.0	3	------	------
			−37.5	324.4	−15.0	------	108	------
			−9.5	352.4	+14.0	3	------	------
			+60.0	61.9	+11.0	------	77	191
May 18 (Naval Observatory)	10	54	−23.0	325.7	−16.0	------	201	------
			−2.5	346.2	+11.0	15	------	------
			+73.0	61.7	+12.0	------	93	309
May 19 (Naval Observatory)	10	55	−10.0	325.5	−15.0	------	262	------
			+14.0	349.5	+11.0	6	------	268
May 20 (Naval Observatory)	11	5	+2.5	324.6	−15.5	------	401	------
			+62.0	24.1	+17.5	3	------	404
May 21 (Naval Observatory)	13	12	−60.0	247.8	+12.0	------	15	------
			+11.0	318.8	−5.0	6	------	------
			+18.0	325.8	−15.0	------	370	391
May 22 (Naval Observatory)	11	8	−40.5	255.2	+10.5	3	------	------
			−10.0	285.7	+10.5	------	9	------
			+31.0	326.7	−13.0	------	31	43
May 23 (Naval Observatory)	11	19	−30.0	252.3	+11.5	------	31	------
			+3.0	285.3	+10.5	------	46	------
			+43.0	325.3	−13.0	------	247	324
May 24 (Naval Observatory)	11	17	−15.0	254.1	+10.5	------	31	------
			+18.0	287.1	+11.0	------	62	------
			+57.0	326.1	−13.0	------	154	247
May 25 (Naval Observatory)	11	11	−2.5	253.4	+10.5	------	46	------
			+30.0	285.9	+11.0	------	15	------
			+43.0	298.9	−10.0	6	------	------
			+70.0	325.9	−14.0	------	108	175
May 26 (Naval Observatory)	10	59	+8.5	251.3	+18.0	3	------	------
			+11.5	254.3	+10.5	------	62	------
			+37.5	280.3	+6.0	------	31	96
May 27 (Naval Observatory)	11	6	+26.0	255.5	+12.5	------	77	------
			+52.0	281.5	+8.0	------	62	------
			+80.0	309.5	+6.0	3	------	142
May 28 (Naval Observatory)	11	5	+45.0	261.3	+12.0	31	------	------
			+68.0	284.3	+8.0	46	------	77
May 29 (Naval Observatory)	11	20	+55.0	257.9	+12.5	------	93	------
			+80.0	282.9	+8.0	3	------	96
May 30 (Naval Observatory)	11	54	−80.0	109.4	+2.5	------	108	------
			+67.0	256.4	+18.0	31	------	139
May 31 (Naval Observatory)	10	51	−70.0	106.7	+5.0	------	93	93
Mean daily area for May	------		------	------	------	------	------	184

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG in Charge]

By L. T. SAMUELS

Free-air temperatures for May were below normal in the lower levels and above normal in the upper levels except at Due West, where the departures decreased appreciably with altitude but remained negative at all levels. (Table 1.)

The relative humidity averaged above normal in the lower levels and mostly below normal in the upper levels.

Vapor pressure departures were in agreement with those for temperature, except that the former remained negative at all levels at Broken Arrow.

The data for Groesbeck have been omitted from Table 1, as kite observations were discontinued at that station on May 16.

Free-air resultant winds for the month at the 1,000-meter level were mostly westerly except on the Pacific coast, where they were very light and variable, and in the extreme southern part of the country, where they were mostly southerly and easterly. (Table 3.)

At 4,000 meters the resultant directions were westerly at practically all stations except in the extreme northern part of the country, where a pronounced northerly component prevailed. The highest resultant velocities at this level occurred over the upper Lakes and New England regions.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	16.6	−3.1	18.5	−1.8	11.4	−1.7	14.9	−1.2
500	15.0	−2.8	16.9	−0.9	10.9	−1.8	12.5	−0.9
1,000	12.9	−2.7	14.5	−0.4	8.7	−0.8	10.0	−0.2
1,500	11.0	−2.4	11.2	−0.6	6.7	+0.1	7.4	0.0
2,000	8.4	−2.4	8.1	−0.8	5.1	+1.5	4.8	−0.2
2,500	5.4	−2.6	5.2	−0.9	2.6	+1.9	2.6	0.0
3,000	2.9	−2.0	2.4	−0.7	−0.2	+1.9	0.3	+0.5
4,000	−1.0	+0.3	------	------	−5.6	+2.4	−4.1	+2.2
5,000	−5.2	+1.4	------	------	−11.6	+2.5	−9.3	+2.8

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow Mean	Departure from normal	Due West Mean	Departure from normal	Ellendale Mean	Departure from normal	Royal Center Mean	Departure from normal
Surface	71	+1	69	+4	62	+2	67	+3
500	70	+1	65	0	62	+2	67	+3
1,000	66	−1	59	−5	59	0	65	+2
1,500	58	−4	59	−5	57	−3	60	−1
2,000	56	−3	57	−5	55	−5	54	−3
2,500	55	−1	55	−4	55	−4	50	−1
3,000	53	−1	47	−8	56	−1	53	+6
4,000	37	−18	------	------	48	−5	47	+1
5,000	21	−32	------	------	50	−1	44	−2

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1931*—Continued

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	13.70	−2.73	14.98	−0.46	8.41	−0.67	11.54	−0.34
500	12.06	−2.32	12.90	−0.53	8.14	−0.69	9.89	−0.22
1,000	9.84	−1.99	10.21	−0.91	6.47	−0.58	8.01	−0.20
1,500	7.48	−1.84	8.37	−0.79	5.58	−0.31	5.97	−0.61
2,000	5.93	−1.48	6.73	−0.57	4.82	+0.05	4.38	−0.73
2,500	4.86	−0.91	5.17	−0.56	4.12	+0.37	3.42	−0.34
3,000	4.00	−0.58	3.74	−0.67	3.49	+0.58	3.25	+0.55
4,000	2.50	−0.57			1.78	+0.13	2.37	+0.85
5,000	1.43	−0.64			1.35	+0.42	1.69	+0.91

TABLE 2.—*Free-air data obtained by airplanes at naval air stations during May, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)					Relative humidity (%)				
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.
Surface	18.7	22.0	19.4	18.8	16.4	70	74	72	60	66
500	15.9	19.2	15.8	14.1	15.2	62	73	83	66	59
1,000	13.8	16.7	15.7	10.1	13.8	58	63	67	64	54
2,000	8.7	10.7	13.4	3.2	9.4	45	53	37	61	47
3,000	2.0	4.8	6.2	−1.8	3.7	45	49	27	51	41
4,000					−0.7					11

TABLE 3.—*Observations by means of kites, captive and limited-height sounding balloons during May, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,853	2,727	3,268	2,498	3,366
Maximum altitude (meters), m. s. l., reached	[1] 5,906	3,570	[1] 5,600	3,840	[1] 5,737
Number of flights made	33	31	31	[2] 9	30
Number of days on which flights were made	31	30	30	[2] 9	29

[1] Limited-height sounding balloon observation.
[2] Covers period from May 1 to 16, inclusive, only.

In addition to the above, there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during May, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N	0.6	S 51 E	1.0	S 44 W	2.9	N 70 W	3.3	S 18 W	0.3	S 10 W	2.0
500			S 23 E	6.0	S 25 W	5.7			S 74 W	3.0	S 45 W	4.7
1,000			S 14 E	5.5	S 76 W	5.5			N 85 W	5.4	S 80 W	5.2
1,500			S 10 E	4.4	S 87 W	7.1			S 88 W	6.8	S 81 W	5.3
2,000	S 74 W	1.1	S 6 W	3.2	S 86 W	7.9	N 73 W	5.6	S 85 W	7.4	S 83 W	6.0
2,500	N 77 W	4.2	S 32 W	2.3	N 89 W	8.9	N 63 W	8.0	S 82 W	7.5	S 83 W	6.5
3,000	N 67 W	6.3	N 69 W	2.4	N 72 W	12.1	N 55 W	9.0	N 89 W	5.5	S 66 W	6.3
4,000	N 76 W	7.3	N 65 W	7.0	N 78 W	8.9	N 49 W	10.0			N 81 W	4.3
5,000	S 79 W	6.9	N 59 W	10.0			N 71 W	8.6				

Altitude (meters) m. s. l.	Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 21 E	0.8	N 84 W	0.5	N 37 W	2.4	S 85 W	1.1	N 77 W	0.6	N 57 E	1.7
500	S 22 W	3.3	W	3.4	N 45 W	2.5			S 69 W	1.2	N 79 E	3.2
1,000	S 59 W	4.2	S 76 W	3.7	N 84 W	2.5	S 76 W	3.2	S 48 W	1.8	S 86 E	2.4
1,500	S 71 W	4.7	S 87 W	3.4	N 59 W	3.4	N 89 W	3.4	S 58 W	1.5	S 65 E	0.7
2,000	N 83 W	4.2	S 87 W	4.1	N 38 W	5.4	N 72 W	4.5	S 62 W	2.2	S 22 W	1.3
2,500	N 84 W	4.9	W	4.8	N 35 W	5.8	N 70 W	4.2	S 63 W	3.0	S 43 W	1.9
3,000	N 70 W	5.1	N 76 W	3.9	N 37 W	5.3	N 67 W	4.0	S 84 W	3.6	S 76 W	2.5
4,000	N 75 W	4.8	N 49 W	4.2	N 26 W	6.2	N 69 W	6.1	N 85 W	5.8	N 80 W	3.9
5,000	N 44 W	3.6	N 66 W	4.3	N 38 W	6.8	N 49 W	6.9	S 89 W	6.2	N 71 W	6.3

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma, City, Okla. (392 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 66 E	0.8	N 79 W	0.3	S 51 W	0.9	N 29 E	0.5	N 8 W	1.6	S 37 W	1.0
500	S 75 E	1.0	N 66 W	0.6	S 85 W	3.5	S 70 W	0.5	N 24 E	1.4	S 40 W	2.5
1,000	N 83 W	1.7	N 58 W	0.8	N 89 W	5.3	S 50 W	1.8	N 16 E	4.3	S 79 W	5.4
1,500	S 59 W	2.7	N 61 E	0.7	N 78 W	6.2	S 62 W	3.3	N 29 E	3.5	N 84 W	4.5
2,000	N 60 W	1.4	N 15 E	1.2	N 77 W	6.2	S 79 W	3.1	N 22 E	4.4	N 85 W	6.0
2,500	S 81 W	2.8	N 41 W	1.8	N 71 W	5.5	N 87 W	3.8	N 7 E	3.6	N 77 W	6.2
3,000			N 46 W	3.6	N 70 W	3.8	N 72 W	4.8	N 21 W	7.5	N 71 W	4.8
4,000			N 56 W	6.2			S 89 W	6.6			N 70 W	5.7
5,000							N 57 W	4.8				

Altitude (meters) m. s. l.	Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 14 E	0.8	N 66 E	0.9	S 28 E	2.7	N 27 E	0.5	S 32 E	0.5	S 54 W	0.9
500	N 6 W	0.8	N 83 E	0.8			N 87 E	0.6	N 12 W	0.9	N 84 W	3.7
1,000	N 86 W	2.9	N 28 W	0.4			N 79 W	1.8	S 50 E	0.4	N 59 W	4.9
1,500	N 79 W	4.5	N 67 W	1.3	S 15 E	3.5	N 65 W	3.7	S 53 W	1.0	N 79 W	6.0
2,000	N 79 W	5.6	N 73 W	1.5	S 24 W	2.5	N 79 W	5.3	N 79 W	3.2	N 80 W	6.9
2,500	N 66 W	5.5	S 76 W	2.1	S 83 W	3.5	N 79 W	7.0	N 82 W	5.2	N 76 W	5.9
3,000	N 64 W	7.2	S 72 W	2.1	N 87 W	4.4	N 72 W	8.8	N 63 W	4.8	N 80 W	4.9
4,000	N 79 W	6.2	S 57 W	2.8	N 72 W	6.9	N 25 W	10.8			N 79 W	4.9
5,000	N 52 W	7.7	N 70 W	6.2			N 27 W	12.8				

WEATHER IN THE UNITED STATES

[Climatological Division, Oliver L. Fassig, in Charge]

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

For May as a whole temperature averaged from 2° to 6° below normal from western Ohio, middle Mississippi and lower Missouri valleys southward, while generally in the northern Great Plains and west of the Rocky Mountains the month was decidedly warmer than normal. Abnormally low temperatures prevailed about the 20th of the month with freezing weather as far south as Iowa and parts of Kansas. Thereafter warmer weather prevailed, with high temperatures the latter part of the month in the interior and Eastern States. The precipitation during the month was unevenly distributed, but considerable areas, especially in the East, had more than the normal amounts. Many portions of the Atlantic States from Florida to New England received from 25 to 50 per cent more than the average for the month, and other areas in the interior comprising northern Illinois and Missouri and portions of the Southwest had more than normal. Large deficiencies occurred in the Central Gulf States and the Northwest between the Lake region and the Rocky Mountains, as well as in the Pacific Northwest. But the smallest percentages of normal occurred in the eastern portions of Washington and Oregon and much of Arizona where less than 25 per cent of the normal was recorded.

TEMPERATURE

West of the Continental Divide warm weather prevailed nearly all the month, and in the extreme Northwest the first half of the middle decade was especially notable for high temperatures.

From the Rocky Mountains eastward cool and warm periods alternated. A well-marked cool period affected nearly all of the middle and eastern sections about the 6th to 13th, but somewhat higher temperatures succeeded, especially in the upper Mississippi Valley, Lake region and Northeastern States.

A notable cool spell set in over the northern Plains about the 18th and advanced southward and eastward, reaching the Atlantic coast about the 22d; the duration of the cool weather was usually about four days, and the remainder of the month was marked by practically normal temperatures in most middle and eastern sections, save that high marks were reached from the 27th to the 31st in much of the Lake region and especially in the Middle and North Atlantic States.

In nearly all States east of the Rocky Mountains the month averaged cooler than normal, especially in the middle and southern Plains, the west Gulf region and the central valleys, where it averaged usually 3° to 5° cooler. In some Southeastern and South-Central States it was the third successive month to average considerably cooler than normal, and save February no month since September, 1930, has been warmer than normal in these sections. On the other hand, in Michigan, Wisconsin, Iowa, Minnesota, and South Dakota, May was the first month since October, 1930, to average cooler than normal.

Pennsylvania, New Jersey, New York, and New England averaged slightly warmer than normal, likewise North Dakota. In Montana and the Plateau and Pacific States the month was warmer than normal, usually to a marked extent. California averaged almost 6° hotter than normal, and in that State and Nevada every month so far this year has averaged at least 1° above. The warmth since early March in southern California has been particularly notable. Los Angeles recorded no spring month previous to 1931 warmer than May, 1885, when the mean temperature was 65.6°. This year March and April each averaged 66°, 8.5° and 6.6° above normal, respectively, amd May 67.5°, 5.3° above normal.

The highest temperatures during May in the States of the eastern half were usually from 93° to 98°, and occurred chiefly about the middle of the month or during the last five days. Marks above 100° were noted in nearly every State of the western half, the highest being 114° in California. These occurred usually about the 14th, on the 25th, or during the final two days.

In some Gulf States the lowest temperatures were as high as 40°, but mainly they were from 10° to 30°, save below 10° in some Rocky Mountain States. The dates of occurrence were scattered through the month, many Northeastern States noting them on the 1st, and other Eastern and Middle States, as a rule, either about the 8th or 12th, or else between the 20th and 24th.

PRECIPITATION

The rainfall for the western half of the cotton region, which was poorly distributed and mainly much below normal, occurred chiefly during the opening week, or about the 20th; while in the eastern cotton region the distribution was better, yet most districts had by far the greater part of the month's supply during the first fortnight. The upper Ohio Valley had liberal rains about the middle of the month. In the Atlantic States from North Carolina northeastward the most important rains came near the close of the first decade or during the final decade.

The precipitation of the central valleys and the Lake region was comparatively well distributed in point of time, but much occurred about the 19th. The central Rocky Mountain region received its most important falls during the early days or else about the 28th.

The monthly totals were less than normal over considerably the larger part of the country. In the middle and upper Missouri Valley and thence westward to the north Pacific coast there was a marked deficiency, particularly in Idaho, Oregon, the eastern half of Washington and northern Montana, which usually received but one-quarter to two-fifths of the normal. The western half of the country otherwise had usually less than normal, save some parts of central and southern California, a strip extending from northeastern Colorado to the Texas Panhandle, and most of the lower Rio Grande Valley.

In the eastern half there was usually less than normal in the Gulf States, Arkansas, Tennessee, and the southern Appalachian region, in most of the lower Ohio and upper Mississippi Valleys and in much of the Lake region, especially near Lakes Erie and Huron. From northeastern Florida to central New England there was nearly everywhere an excess and a rather large excess occurred in the middle Appalachian region and the upper Ohio Valley. Much of Illinois and the lower Missouri Valley had a slight excess.

The largest amount reported from one station was 12.97 inches at Center Hall, Pa.

This month was the first since October, 1929, to bring more than normal precipitation at Washington, D. C. However, at Charleston, S. C. it was the eleventh consecutive month with less than normal.

In the Missouri Valley and to westward numerous districts have fallen far below their normal precipitation

for many months. At Helena, Mont., every month of the last six has failed to bring as much as half its normal precipitation; while at Sioux City, Iowa, Pocatello, Idaho, and Eureka, Calif., no single month yet this year has brought as much as 70 per cent.

SNOWFALL

There was no important snowfall over the Plains or to eastward, except in a very few districts. About the 20th nd 21st small amounts fell in eastern North Dakota and to eastward to the vicinity of Lake Superior, while three days later there was a moderate snowfall over much of south-central New York and northeastern Pennsylvania. A considerable portion of eastern Colorado and some parts of adjoining States had rather large amounts for the latter half of May about the 21st.

In the Pacific and Plateau States and practically all of Montana the month's snowfall was unimportant. On the other hand, some portions of the Rocky Mountains had much new snow, two Colorado stations each measuring more than 50 inches during the month.

SUNSHINE AND RELATIVE HUMIDITY

The Southwest generally, much of the Great Plains, the southern Rocky Mountains and most of the Plateau and portions of the lower Lake region received more than the normal amount of sunshine, while in the central and upper Mississippi Valley much cloudy weather prevailed. Elsewhere about the usual amount of sunshine for May was received. The relative humidity was below the normal generally from the upper Mississippi Valley westward to the Pacific and also throughout the central portions of the Rocky Mountain and Plateau regions, while in the Atlantic States, the Ohio and central Mississippi Valleys and the far Southwest it was generally above the normal, but the plus departures were in no case large.

SEVERE LOCAL STORMS, MAY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Yakima, Wash	1	2:30 p. m.				Whirlwind	Several small buildings wrecked	Official, U. S. Weather Bureau.
Riogrande, Tex	1	4:30 p. m.	4 mi.		$2,500	Hail	Roofs damaged; glass broken	Do.
Bishop, Tex	2	5 p. m.				Hail and wind	Crops and buildings damaged; path 35 miles long.	Do.
Grand Junction, Colo. (near)	3	5-6 p. m.	1-3 mi.			Hail	Considerable damage to pears	Do.
Stanton, Kearney, Finney, Haskell and Gray Counties, Kans.	4	3-5 p. m.	1-6 mi.		1,500,000	Hail and wind	Heavy loss of crops, chiefly wheat; buildings damaged; path 100 miles long.	Do.
Cimarron, Kans. (near)	4	4 p. m.	6		300	Small tornado	Several small buildings damaged; path 3 miles long.	Do.
Blair and Humphrey, Okla., and vicinity.	4	4-5 p. m.	5 mi.		6,700	Hail	Chief damage to crops; path 15 miles long	Do.
Ness County, Kans	4	4:45 p. m.	900		25,000	do	Damage chiefly to wheat; path 7 miles long	Do.
Davenport, Fla	4	6 p. m.	2,640			do	Young citrus fruits considerably damaged	Do.
Electra, Tex	4	6:30 p. m.				Wind, hail, and rain.	Roofs, chimneys, and merchandise damaged	Do.
Camden, Miss. (near)	4	A. m.			15,000	Tornado and hail	Buildings, fencing, and crops damaged; many large trees uprooted.	Do.
Jefferson and Page Counties, Iowa.	5	9:30-10:30 a. m.			10,000	Wind	Overhead wires and trees considerably damaged.	Do.
Camilla, Ga	5				7,000	Wind, rain, and hail.	Several roofs damaged; trees blown down	Do.
Fredericksburg, Kerrville, and Comfort, Tex.	6	2:30 p. m.	4 mi.		25,000	Wind and hail	Cars and buildings damaged; considerable injury to crops.	Do.
Canning to Onida, S. Dak	6	7-8 p. m.	8 mi.		25,000	Hail and wind	Several small buildings wrecked and other property damaged; 3 children injured.	Do.
Madison, Wis. (11 miles east)	6		50		75	Small tornado	Farm property damaged	Do.
Pittsburgh, Pa	7					Severe thunderstorm.	Streets flooded; electric wires damaged	Do.
Rock Hill, S. C. (near)	7				1,000	Hail	Crops damaged	Do.
Dinwiddie and Prince Georges Counties, Va.	9	6-7 p. m.	¼-4 mi.			Hail and wind	Barns wrecked; fruits ruined in small area	Do.
Parkersburg, W. Va	9				100,000	Severe thunderstorm.	A fire caused by lightning partially destroyed a mill.	Do.
Windsor, N. C., and vicinity	9					Hail	Tobacco beds and other crops damaged; roofs and windows pierced; poultry killed.	Do.
Bascom, Fla	10	3 a. m.	1,760			do	Cotton and corn probably total loss	Do.
Albany, N. Y., and vicinity	10	5:15 p. m.	5 mi.		150,000	do	Poultry killed, auto tops and windows broken; roofs and small buildings damaged; fruit trees stripped; telephone company suffered loss.	Do.
Virginia (southeast counties)	10	4 p. m.	5 mi.		10,000	do	Character of damage not reported	Do.
Burlington County, N. J.	10	7:30 p. m.			300,000	do	Severe crop damage; fruit trees stripped; car tops dented.	Do.
Clinton, N. J., and vicinity	10	7:30 p. m.			25,000	do	Crops injured; some property damaged	Do.
Phelps and Junius, N. Y.	10		1,760			do	Fruit trees hurt; windows broken	Do.
Montrose, Pa	10				5,000	Thunderstorm	Barn and contents destroyed	Do.
Thomas County, Ga. (northwestern).	10		1,760		1,500	Wind, rain, and hail.	Buildings and crops on one plantation damaged.	Do.
Cooperstown, N. Y.	11					Small tornado	A few roofs, trees, and garages damaged	Do.
Greenbrier County, W. Va. (Falling Springs district).	11					Hail	Roofs and auto tops riddled; windows broken; fruit trees stripped; gardens ruined; poultry killed.	Do.
King William and Gloucester Counties, Va.	13	2-4 p. m.	5-10 mi.		6,000	do	Melon and truck crops seriously damaged	Do.
Newman Grove, Nebr.	17	4-5 p. m.	3 mi.		3,000	Wind and hail	Farm buildings damaged; crops injured; path 10 miles long.	Do.
Dickinson County, Iowa	17	5 p. m.			8,000	Tornado and hail	Character of damage not reported	Do.
Osceola County, Iowa	17	5:30 p. m.			5,500	Tornado	Buildings damaged; livestock injured or killed; path 3 miles long.	Do.
Marietta, S. C.	17				1,000	Hail	Crops damaged	Do.
Tennessee (eastern)	17-18					do	Fruit and other young crops damaged	Do.
Russell County, Va	18	2 p. m.	2 mi.			do	Considerable damage, character not reported	Do.
Belmont and adjacent counties, Ohio.	18-19				100,000	do	Crops, buildings, and other property severely damaged.	Do.
Sallis, Miss. (4 miles west)	19	A. m.				Violent wind	A barn and residence demolished; 1 person injured; storm covered about an acre.	Do.

[1] "Mi" signifies miles instead of yards.

Severe local storms, May, 1931—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cumberland County, Pa. (western).	19	P. m.			10,000	Severe thunderstorm.	Barn burned; many small buildings damaged.	Official, U. S. Weather Bureau.
Comanche, Tex.	19		1,760		2,500	Hail	Crops and buildings damaged	Do.
Terra Haute, Ind. (near)	19				1,500	Wind	Damage to farm buildings	Do.
Mobile, Ala.	20					Thundersquall	Trees blown down; electric service interrupted.	Do.
Clay County, Nebr. (southwestern).	21	3:30 a. m.	3 mi.		5,000	Wind	Character of damage not reported	Do.
Roxana to Skellytown, Tex.	21	2:30 p. m.			40,000	Tornado	Crops and other property severely damaged.	Do.
Albany, Tex.	21	6:30 p. m.			15,000	Hail	Buildings damaged; minor crop injury	Do.
Cotton County, Okla.	21	7 p. m.	880-1,760		52,000	do	Chief damage to crops; path 20 miles long	Do.
Latimer County, Okla. (northern).	21	11 p. m.	2,640		3,000	do	Some damage to crops and other property	Do.
Virginia (southwestern)	22	2-5 p. m.	2-18 mi.		51,000	Hail and wind	Heavy crop loss	Do.
Victor, Dublin, and Carlton, Tex.	22	8 p. m.	9 mi.		40,000	Hail	Crops destroyed or injured; houses damaged; poultry and lambs killed.	Do.
Anna, Ill. (near)	22					do	Injury to property slight to severe	Do.
Caldwell and Burke Counties, N. C.	22				50,000	do	Crops severely damaged; roofs pierced	Do.
Stanley County, N. C.	22					do	Much small grain destroyed; replanting of cotton necessary; gardens total loss.	Do.
Atchison County, Kans.	24	11-12 p. m.	1,300		7,000	Hail and wind	Injury chiefly to apples, pears, and gardens; path 3 miles long.	Do.
Waukesha and Racine Counties, Wis.	24		10 mi.		5,000	Hail	Roofs damaged; trees blown down; fruit injured.	Do.
Snyder, Tex.	25	4 p. m.			3,000	do	Crops damaged	Do.
Lancaster, Ohio	25	4:30 p. m.				Probably tornado.	Character of damage not reported	Do.
Crozet, Va., and vicinity	26	2:30-6:30 p. m.	1,760		40,000	Hail	Trees, fruits, and gardens severely hurt; path 7 miles long.	Do.
Moorhead (10 miles southeast) to Gary, Minn.	27	4:15 p. m.		2	200,000	Tornado	Passenger train lifted from rails; several buildings wrecked; farm machinery damaged; livestock injured or killed; some fields require replanting; 57 persons injured; path 40 miles long.	Do.
Jewell, Rooks, and Osborne Counties, Kans.	27	8-11 p. m.				Hail	Damage chiefly to wheat	Do.
Thomas and Grady Counties, Ga.	27				2,000	do	Crops injured over path several miles long	Do.
Harlan County, Nebr.	28	2 a. m.	1-2 mi.		75,000	Wind	20 barns damaged; many windmills wrecked; path 30 miles long.	Do.
Scott County, Iowa	28	2:30 p. m.	490		2,500	Tornado and wind	Character of damage not reported; path 2 miles long.	Do.
Des Moines County, Iowa	28	3 p. m.				Tornado and hail.	No details reported; path 4 miles long	Do.
Oneida, Ill.	28	4:30 p. m.			5,000	Wind	Buildings damaged; trees uprooted	Do.
Galva, Ill. (south)	28					Severe thunderstorm and wind.	Farm buildings blown down or unroofed; trees uprooted.	Do.
Dawson, N. Mex.	29	2:30 - 3:30 p. m.	2 mi.		1,000	Hail	Gardens and flowers ruined; too early for crops.	Do.
Field, N. Mex. (near)	29	2-6 p. m.	6 mi.		21,000	do	Severe damage, character not reported	Do.
Charlottesville, Va. (near)	30	3:05 p. m.	1,500		9,000	Tornado	Chief damage to airplane hangar and 3 planes.	Do.
Grove City, Pa.	30	6 p. m.	100		5,000	Thundersquall	College buildings damaged	Do.
Bradford County, Pa.	30	P. m.				Thunderstorm and wind.	Damage chiefly to crops	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES, in charge River and Flood Division

Overflows in the southern part of the Atlantic slope drainage caused miscellaneous damage to the extent of about $8,000. Timely forecasts were issued and were generally heeded, which reduced the losses to a minimum.

Minor local floods in the Kansas, Canadian, Guadalupe, Pecos, and Colorado Basins caused no damage of consequence.

Stages are very low throughout most of the Mississippi River system, and many stations report the lowest of record for May. Streams are also low in the Pacific slope drainage.

Final reports of the overflows in the Columbia River Basin in March and April indicate the flood damage was about $10,000 along streams where a flood-warning service is maintained. Along streams where there is no warning service the damage amounted to about $50,000. Savings effected through the warnings were estimated at $25,000. At Walla Walla, Wash., there was a severe flood in Mill Creek, destroying or damaging property to the extent of $500,000.

Table of flood stages in May, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Tar: Rocky Mount, N. C.	9	10	10	9.0	10
Neuse: Smithfield, N. C.	14	24	26	14.8	25
Cape Fear: Elizabethtown, N. C.	22	23	26	26.6	24
Peedee:					
Cheraw, S. C.	27	23	24	28.6	23
Mars Bluff Bridge, S. C.	17	25	29	18.4	27
Saluda: Pelzer, S. C.	7	21	22	7.4	22
Santee: Rimini, S. C.	12	9	10	12.0	10
		24	27	12.7	27
Oconee: Milledgeville, Ga.	22	5	5	23.5	5
Altamaha: Charlotte, Ga.	15	13	15	15.4	14
MISSISSIPPI SYSTEM					
Missouri Basin					
Solomon: Beliot, Kans.	18	6	6	20.4	6
Republican: Concordia, Kans.	8	5	5	8.3	5
Arkansas Basin					
Canadian: Logan, N. Mex.	4	2	2	5.6	2
		4	4	5.0	4
		30	30	6.0	30
WEST GULF OF MEXICO DRAINAGE					
Guadalupe: Victoria, Tex.	16	5	5	16.2	5
Pecos: Pecos, Tex.	11	1	2	11.6	1
		5	5	11.0	5
GULF OF CALIFORNIA DRAINAGE					
Colorado: Parker, Ariz.	7	24	31	7.9	25-26

THE WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[Marine Division, W. F. McDONALD, in charge]

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather over the eastern section of the ocean during May was somewhat quieter than usual, gales occurring on from one to four days in different 5° squares in that region. Over the western section disturbances of any importance were unusually rare, as gales were not reported on more than one day in any 5° square west of the forty-fifth meridian.

The comparatively small departures at most of the coast and island stations as shown in Table 1, indicate that the pressure distribution over the greater part of the ocean was not far from normal.

The most unusual feature of the month was the remarkably severe disturbance near the Equator on the 2d, as reported by the observer on board the Norwegian M. S. *Ima*, and shown in table of gales and storms.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian) North Atlantic Ocean, May, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Belle Isle, Newfoundland	29.87	[1] −0.07	30.40	24th	29.20	4th.
Halifax, Nova Scotia	29.98	[2] +0.01	30.28	7th	29.54	15th.[3]
Nantucket	29.96	[2] −0.03	30.20	1st [3]	29.56	14th.
Hatteras	29.93	[2] −0.04	30.24	28th	29.64	13th.
Key West	29.96	[2] −0.02	30.12	15th [3]	29.82	31st.
New Orleans	30.00	[2] 0.00	30.20	15th	29.82	9th.
Turks Island	30.00	[1] 0.00	30.12	16th	29.92	30th.[3]
Bermuda	30.05	[2] −0.06	30.26	19th [3]	29.86	14th.
Horta, Azores	30.16	[1] +0.02	30.32	2d [3]	29.90	8th.
Lerwick, Shetland Islands	29.82	[1] +0.02	30.19	8th	29.36	15th.
Valencia, Ireland	29.75	[1] −0.20	30.20	8th	29.34	29th.
London	29.87	[1] −0.05	30.25	9th	29.46	17th.

[1] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date or dates.

As in April, fog was unusually prevalent over the western section of the ocean, and the number of days on which it was reported in different localities is as follows. Over the Grand Banks, from 12 to 14 days; along the American Coast between the thirty-fifth and fortieth parallels, on 12 days; along the American coast north of the fortieth parallel, from 12 to 16 days; over the steamer lanes between the tenth and fortieth meridians, from 1 to 2 days; off the coast of Europe, from 1 to 5 days; in the Gulf of Mexico, on 3 days.

During the first four days of the month moderate conditions prevailed generally, except for the depression that was off the south coast of Newfoundland on the 4th, and afterwards developed into a disturbance that reached its greatest intensity on the 7th and 8th, and is shown on Charts VIII to XI covering the period from the 5th to 8th.

A second disturbance that was over the mid-eastern section of the steamer lanes on the 11th moved slowly eastward and on the 13th was centered about 300 miles west of Valencia, Ireland.

From the 17th to the 23d moderate to strong gales were reported by a number of vessels over a considerable area in mid-ocean, while during this period moderate weather prevailed west of the fortieth meridian.

From the 24th until the end of the month there ensued a period of comparatively slight wind movement, and few reports were received from vessels encountering a wind force of 7 or over, although on the 29th the land stations at Cape Race, Newfoundland, and Lerwick, Shetland Islands, both reported winds of force 8 with rain.

Notes.—British steamship *Coronado*, Capt. A. W. Legge; observer, G. Binks, third officer. From Avonmouth to Jamaica:

Sunday, May 10, 1931, at 2.30 p. m. A. T. S., in latitude 21° 34′ N., longitude 71° 05′ W., observed a waterspout bearing WSW., approximate distance 10 miles. Barometer 29.91 inches. Clouds Cu. Nb. 2. The spout was vertical and very well defined, very dark at the top, base becoming lighter in the middle. The sea at the base was disturbed and rose up conically to the spout that lasted about 5 minutes, finally being dispersed in a heavy rain squall. Half an hour later while lying off Grand Turk another waterspout was observed appearing to lie over Caicos Island. This spout was identical in size and shape to the former and lasted about 7 minutes, finally dispersing in heavy rain.

Lekhaven, Dutch steamship, Capt. T. Yaski; observer, Y. M. Groenweg, second officer. From Buenos Aires to Amsterdam:

At 5 a. m. May 26, 1931, in latitude 34° 40′ N., longitude 15° 32′ W., saw a waterspout, distance about 6 miles, height about 10 degrees. Wind SW., 2. Barometer 30.03 inches. Temperature, air 65°; water 65°. Blue sky, smooth sea, slight confused swell.

OCEAN GALES AND STORMS, MAY, 1931

Vessel	Voyage From—	Voyage To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Ima, Nor. M. S.	Singaporo	Lands End	3 10 N	12 08 W	May 2	1 p. 2	May 2		NE	NE, 8	NE	NE, 9	Steady.
Greystoke Castle, Br. M. S.	Port Said	New York	39 23 N	65 00 W	May 3	9 a. 3	May 3	29.74	S	S, 7	W	—, 8	S-SSW.
Boston City, Br. S. S.	Fowey	Portland, Me.	45 13 N	38 52 W	May 4	2 p. 6	May 8	29.54	S	WNW	NW	NW, 9	W-WNW.
General von Steuben Ger. S. S.	Southampton	New York	43 14 N	43 31 W	May 6	9 a. 6	May 7	29.57	W	WSW, 7	NW	WNW, 9	
East Indian, Am. S. S.	Antwerp	do	45 30 N	42 15 W	May 7	2 p. 7	May 8	29.16	WNW	W, 9	NNW	WNW, 10	W-NNW.
Sarcoxie, Am. S. S.	Harve	do	46 41 N	30 25 W	do	7 a. 7	do	29.28	S	W, 10	W	W, 10	S-W.
Tulsa, Am. S. S.	Manchester	Savannah	50 08 N	19 50 W	May 10	1 p. 10	May 10	29.48	SSW	SSW, 9	W	SSW, 9	SSW-W.
Bellhaven, Am. S. S.	Boston	Manchester	48 31 N	38 50 W	do	Mdt. 11	May 13	29.01	SW	SW, 7	WNW	W, 11	SW-W.
Dresden, Ger. S. S.	Bremerhaven	New York	48 54 N	26 06 W	May 11	8 p. 11	May 12	29.37	SSW	SW, 10	WNW	W, 10	
Statendam, Du. S. S.	Rotterdam	do	47 50 N	25 36 W	do	10 a. 12	May 13	29.67	SSW	WSW, 8	WNW	WSW, 9	WSW-W.
Europa, Gr. S. S.	Cherbourg	do	49 04 N	19 24 W	May 12	2 a. 13	do	29.54	SSW	WSW, 7	W	W, 10	WSW-W.
Bannock, Am. S S.	Cork	do	50 43 N	30 42 W	May 17	2 a. 17	May 20	29.37	SW	SW, 6	NW	W, 10	SW-W.
Ambridge, Am. S. S.	Antwerp	do	49 08 N	21 58 W	do	Noon 17	May 18	29.23	WNW	WNW, 8	NW	WNW, 10	WNW-NW.
Meanticut, Am. S. S.	Rotterdam	Galveston	46 17 N	14 41 W	do	do	do	29.34	W	W, 7	NW	WNW, 10	W-WNW.
Ambridge, Am. S. S.	Antwerp	New York	46 49 N	31 23 W	May 19	Noon 19	May 22	29.87	WSW	WSW, 7	W	W, 10	
Jean Jadot, Belg. S. S.	do	do	47 00 N	30 00 W	May 21	4 p. 21	do	29.51	NW	NW, 8	NW	—, 10	
Elmsport, Am. S. S.	Hull	Jacksonville	42 05 N	21 10 W	do	6 p. 21	May 23	29.63	WNW	NW, 10	WNW	NW, 10	WNW-NW.
Gonzenheim, Ger. S. S.	Emden	Baltimore	50 43 N	17 33 W	May 22	4 a. 23	May 24	29.13	ESE	NE, 10	NNW	N, 10	NE-N.
SOUTH ATLANTIC OCEAN													
Lekhaven, Du. S. S.	Buenos Aires	Amsterdam	32 40 S	49 10 W	May 3	Noon 5	May 6	29.67	SW	WNW, 8	WSW	WNW 9	
Portfield, Br. S. S.	Penarth	River Plate	34 30 S	53 00 W	May 19	8 p. 19	May 20	29.37	SW	SW, 8	SW	SW, 9	Steady
NORTH PACIFIC OCEAN													
Golden Star, Am. S. S.	Houg Kong	San Fraucisco	43 10 N	159 35 E	Apr. 30	6 p. 30	May 1	29.03	SE	SE, 8	SW	SE, 9	SE-SW.
Chattanooga City, Am. S. S.	Kahuilui	Kobe	30 05 N	154 30 E	May 1	8 a. 2	May 2	29.65	SW	W, 8	N	W, 8	SW-W-WNW
Grays Harbor, Am. S. S.	Hong Kong	San Francisco	27 08 N	123 58 E	May 7	2 p. 8	May 8	29.92	NW	NNW, 8	N	NNW, 8	N-NNW.
Resolute, Ger. S. S.	Hilo	do	37 17 N	123 38 W	do	Mdt. 7	do	30.09	NNE	N, 8	N	N, 9	Steady.
Golden Star, Am. S. S.	Hong Kong	do	[1] 47 00 N	154 00 W	May 8		May 9		SSE		WNW	SW, 11	
Silveryew, Br. M. S.	San Francisco	Yokohama	45 54 N	170 40 E	May 9	4 p. 9	May 10	29.68	SW	SW, —	NNW	W, 10	SW-W.
Pres. Taft, Am. S. S.	Victoria	do	50 14 N	177 04 E	do	1 a., 10	do	29.12	S	WSW 8	NW	WNW, 9	WSW-W-WNW
Fukuyo Maru, Jap. S. S.	Japan	Coos Bay	46 35 N	166 35 E	May 8	10 p. 8	May 12	[2] 29.69	SW	WSW, —	WNW	WNW, 9	
San Diego Maru, Jap. M. S.	Elwood	Kudamatsu	33 25 N	137 25 E	May 11	6 p. 12	May 13	29.72	E	NE, 10	NE	NE, 10	E-NE.
Everett, Am. S. S.	Tacoma	Yokohama	51 37 N	172 00 W	May 12	6 p. 12	do	29.33	NE	NE, 7	NW	NW, 9	N-NW.
Chief Capilano, Br. S. S.	Yokohama	Port Alberni.	49 11 N	179 37 W	May 13	2 p. 13	May 14	29.05	E	NNE, 7	NW	NNE, 8	NNE-N-NNW.
Shelton, Am. S. S.	Aomori	San Francisco	48 20 N	156 30 W	May 15	2 a. 15	May 16	[2] 29.27	WNW	WNW, 8	W	N, 9	WNW-W.
Oregon, Am. S. S.	Weihaiwei	do	32 41 N	133 54 E	do	Noon 15	do	29.37	SE	SE, 11	WSW	SE, 11	SE-SSE.
Emidio, Am. S. S.	San Pedro	Vancouver	35 40 N	121 36 W	May 16	6 p. 16	May 19	30.02	NW	NW, 7	N	N, 9	
Silverhazel, Br. M. S.	Honolulu	San Francisco	37 15 N	123 30 W	May 17	8 a. 18	May 18	30.15	NNW	NNW, 8		NNW, 10	Steady.
Everett, Am. S. S.	Tacoma	Yokohama	39 00 N	144 05 E	May 22	6 p. 23	May 24	29.22	SE	S, 8	NNW	SE, 10	SE-S-NW.
Hakubasan Maru, Jap. M. S.	Yokohama	San Francisco	[3] 42 27 N	162 15 W	May 25	— 25	May 26	[3] 29.30	NNE	NNE, —		NNE, 9	NNE-SSE.
SOUTH PACIFIC OCEAN													
Brunswick, Pan. M. S.	San Pedro	Auckland	35 00 S	177 00 E	May 7	4 a. 8	May 8	[2] 29.44	NNE	SE, 10	SSE	SE, 10	ENE-SE.
Crown City, Am. M. S.	Port Lincoln	Shanghai	35 34 S	122 46 E	May 9	Noon 11	May 13	29.25	NE	NW, 10	SW	NW, 11	NE-N-NW.

[1] Position approximate. [2] Barometer uncorrected. [3] From G. M. N. observation.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—Sharp contrasts of atmospheric pressure between different periods of the month occurred over most of the Aleutian region and the Gulf of Alaska during May, 1931. For the first 17 days a fairly strong development of the Aleutian cyclone was in evidence, and for the last 14 days a considerable reversal of the LOW in favor of strong high pressure occurred, with barometer readings as high as 30.60 inches on the 19th and 22d, so that the average for the month showed practically normal pressure over the entire gulf and the Aleutians.

In the region usually occupied by the North Pacific HIGH there were few intruding low-pressure areas in May, and none of a marked stormy nature, the anticyclone remaining generally in a well developed state in west longitudes.

In middle latitudes on the Asiatic side of the ocean pressure was unstable, and numerous LOWS appeared, some of continental and some of oceanic origin. These caused frequently unsettled weather, such as is characteristic of the transition period between the summer and winter monsoons.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, May, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1, 2]	30.11	+0.02	30.90	1st	29.44	24th.
Dutch Harbor [1]	29.88	+0.04	30.64	22d	29.08	10th.
St. Paul [1, 2]	29.88	+0.04	30.60	22d	29.04	5th.
Kodiak [1]	29.79	−0.05	30.60	19th	29.16	4th.[3]
Midway Island [1]	30.09	+0.04	30.30	19th	29.68	1st.
Honolulu [4]	30.03	−0.02	30.13	15th	29.92	20th.
Juneau [4]	29.97	−0.02	30.60	19th	29.39	23d.
Tatoosh Island [4, 5]	30.09	+0.05	30.59	18th	29.67	21st.
San Francisco [4, 5]	29.94	−0.04	30.18	17th	29.75	21st.
San Diego [4, 5]	29.93	0.00	30.03	23d	29.84	25th.

[1] P. m. observations only.
[2] For 30 days.
[3] And on the 10th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—With the near approach of summer there was a considerable diminution of storminess over

the upper and middle waters of the North Pacific, and no severe disturbances seem to have occurred in the tropics. The regions over which the principal gales of the month occurred may be grouped as follows: One lying immediately south of Japan; another stretching southwestward from the western Aleutians well toward northern Japan; a third running closely along the American coast between Vancouver Island and about Point Conception, Calif.

The gales in lower Japanese waters were mostly caused by two cyclones which came from the Asiatic mainland near the middle of the month. The earlier passed along the lower coasts of the islands and caused strong to whole gales on the 12th. The second cyclone at time of greatest intensity was central over the Japan Sea on on the 15th, during which day gales with force as high as 11 occurred in the southern quadrants east of Kiushu Island. On the 23d, in connection with another cyclone over the Archipelago, a whole southeast gale was reported near the east coast of Honshu.

For that portion of the upper steamship routes lying southwest of the Aleutians the principal gale period embraced the 9th to 11th, with local maximum wind forces of 9 and 10 on the 9th. On other days scattered gales were encountered by steamships, but none was reported as exceeding force 8.

In the American coastal region northerly to westerly gales occurred on the 7th to 9th, and again on the 17th to 19th. In the earlier period the high velocities were due to the steep pressure gradients on the eastern slope of the Pacific anticyclone impinging upon a LOW, the western side of which bordered on the coast. At this time the strongest gale reported was of force 9, experienced about 100 miles west of San Francisco. In the second period there was a strong concentration of the ocean HIGH off the Washington and Oregon coasts, and in consequence of steep gradients east of the crest anticyclonic gales of force 8 to 10 roughened the weather off Oregon and the upper half of California, with moderate gales (force 7) covering a wider range of sea.

The only severe gale mentioned for the entire ocean area apart from the regions noted was a southwesterly wind of storm force (11) reported on the 8th in approximately 47° N., 154° W., this locality being at the time under the influence of the Aleutian disturbance.

Winds at Honolulu.—At Honolulu the prevailing direction of the wind during May was from the northeast, with maximim velocity 25 miles from the east on the 4th. An unusually large number of *konas*, or southerly winds, was reported.

Fog.—Fog showed a distinct increase in frequency over that of April throughout the western part of the upper routes. It was reported on 20 days for the whole region between latitudes 40° and 50° N., and longitude 180° and the Japanese coast. It was most frequent between longitudes 150° and 170° E., where it formed in some 5-degree localities on approximately one-third of the days of the month. East of 180°, in these latitudes, fog occurrence diminished to three or less days per 5-degree square, except east of 160° W., where it became slightly more frequent. Between 40° and 45° N., 130° and 140° W., the whole area seems to have been mantled in fog during the first five days. Between Tatoosh Island and San Diego, 10 to 20 per cent of the days had fog, the highest percentage forming near the coast below San Francisco.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By Giles Slocum

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5-degree subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for May of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the May, 1930, means from the 11-year means for May, 1920–1930, and the changes from the temperatures, for the preceding month of April, 1930.

The chart shows the number of observations taken during the month of May, 1930, within each 1-degree square; the mean temperature of the Straits of Florida, and of each 5-degree[1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

May is a month of rapid warming of the surface water in the Straits of Florida, being second only to June in this respect, while in the Caribbean Sea, the greatest upward change in the temperature takes place, on the average, during this month. The amount of this rise in temperature averages somewhat more than 1° in the Caribbean Sea, and nearly 2½° in the Straits of Florida.

During May the principal discharge from the Caribbean Sea, at the Yucatan Channel, begins to follow summer tracks, with relatively little of the water taking the direct route north of Cuba and out the Straits of Florida. A considerable bulk of the water makes instead a circuit of the entire Gulf of Mexico. Summer conditions have begun to prevail in the Mexican and Gulf States littoral, and consequently, the near-by land is slightly warmer than the sea currents over most of the route.

The water from the Caribbean, mixed with that from more local Gulf currents, finally approaches the vicinity of the Straits of Florida from the west and northwest, having been flowing at all times during the circuit, with relatively low velocity. Examination of current charts indicates that the rates of flow during May are such that the currents setting north and northwest from the Yucatan Channel at this time can hardly complete more than a minor fraction of their circuit in a month; it is therefore presumable that in the latter part of May and in early June, the current through the Straits of Florida may normally contain a minimum of direct flow from the Caribbean through the Yucatan Channel past the northwestern coast of Cuba.

Temperatures were somewhat above the average, during the month of May, 1930, in the region immediately southwest of the Leeward Islands and generally in the Caribbean Sea west of 75° W., and approximately

[1] In three cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5-degree subdivisions.

average for the region about the Windward Islands and between Haiti and Porto Rico on the north, and the South American coast on the south, making the Caribbean Sea, as a whole, warmer than the 11-year mean at all times during the month.

TABLE 1.—*Lengths of "quarter months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for May, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	44	81.0	12	77.7
1920	180	80.2	32	78.6
1921	173	79.8	44	77.4
1922	190	79.8	76	79.2
1923	393	80.0	107	78.8
1924	328	81.1	108	79.0
1925	362	80.4	137	79.0
1926	355	81.3	124	79.0
1927	462	81.2	160	79.7
1928	380	80.7	143	77.6
1929	483	79.9	146	79.8
1930	526	81.0	158	79.6
Mean (1920–1930)		80.5		78.9

[1] Not used in computations because of insufficient data available.

The Florida Straits were also warmer than the average. Particularly noticeable was a protracted period, beginning with the second quarter of April and persisting throughout May, in which the mean temperature showed a rapid, uninterrupted, and remarkably uniform rise. Because of the rapidity of this rise, there was a rather extreme contrast between the temperature of any given quarter in May and the corresponding part of April.

TABLE 3.—*Mean sea-surface temperatures (°F.), and number of observations, May, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	May 1–7	128	80.7			39	78.3		
II	May 8–15	122	81.1			43	79.1		
III	May 16–22	165	81.2			36	80.2		
IV	May 23–31	111	81.2			40	81.0		
Month		526	81.0	+0.5	+1.6	158	79.6	+0.7	+3.1

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1931

[For description of tables and charts, see January, 1931, REVIEW, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	68.6	−2.7	2 stations	96	[1]27	St. Bernard	38	24	3.35	−0.59	Highland Home	6.93	Tuskegee	0.63
Arizona	69.4	+1.5	do	113	31	Alpine	18	19	0.29	−0.05	Tucson Airport	2.16	36 stations	0.00
Arkansas	65.2	−3.9	Hope	96	27	Dutton	27	7	3.45	−1.66	Danville	6.18	Hope	0.74
California	66.3	+5.9	Greenland Ranch	114	[1]30	Madeline	23	19	1.03	−0.06	Huntington Lake	3.87	10 stations	0.00
Colorado	51.0	−1.4	Las Animas	101	[1]13	3 stations	4	[1]8	1.69	−0.05	Fremont Experiment Station.	4.95	Rifle	0.15
Florida	74.2	−1.4	2 stations	97	[1]21	Carrabelle	44	17	3.35	−0.62	Eustis	8.77	Tallahassee	0.83
Georgia	69.7	−1.9	do	98	31	Clayton	33	24	3.45	+0.02	Fort Valley	8.72	Brunswick	0.35
Idaho	55.1	+2.3	Kooskia	100	13	Obsidian	12	[1]8	0.66	−0.92	Preston	2.30	3 stations	0.00
Illinois	59.4	−3.2	Mount Carmel	94	28	La Harpe	28	7	4.25	+0.29	Anna	7.29	Galena	2.01
Indiana	59.3	−2.8	2 stations	95	[1]17	Marengo	28	8	2.96	−1.10	Boonville	6.85	Leavenworth	1.27
Iowa	57.5	−2.6	Inwood (near)	98	26	2 stations	21	7	2.96	−1.62	Denison	5.65	Rock Rapids	1.11
Kansas	60.5	−2.7	2 stations	99	[1]15	Oberlin	25	20	2.89	−0.75	Reading	8.12	Hoxie	0.57
Kentucky	62.7	−2.6	do	97	[1]29	Paducah (near)	30	9	2.59	−1.41	Jenkins	5.60	Frankfort	0.38
Louisiana	69.9	−3.7	Lake Providence	97	28	3 stations	40	13	3.24	−1.19	Angola	10.86	Minden	0.52
Maryland-Delaware	62.3	−0.1	4 stations	95	[1]29	Oakland, Md.	23	[1]1	4.50	+1.13	Western Port, Md.	7.64	Great Falls, Md.	2.20
Michigan	53.7	−0.1	Black Lake	95	28	Wolverine	13	1	3.21	+0.02	Grayling	5.24	Marquette	1.65
Minnesota	53.7	−0.8	Beardsley	98	16	Beardsley	17	7	2.29	−0.77	Pine River Dam	5.25	Bird Island	0.92
Mississippi	68.6	−3.0	Greenwood	97	29	Port Gibson	41	13	3.99	−0.45	Poplarville	9.23	Austin	1.85
Missouri	61.0	−3.4	2 stations	96	16	4 stations	29	7	4.55	−0.12	Mexico	8.05	Caruthersville	1.62
Montana	53.7	+2.6	do	99	[1]13	Loweth	7	18	0.92	−1.23	Mystic Lake	3.09	Red Lodge (near)	T.
Nebraska	57.5	−1.6	Culbertson	102	15	Gordon	12	21	2.23	−1.30	Lincoln (University Farm).	7.17	Sutherland	0.10
Nevada	60.3	+3.9	Las Vegas	108	31	Zorra Vista Ranch	19	21	0.38	−0.43	Marlette Lake	1.51	Searchlight	0.00
New England	56.1	+1.2	3 stations	95	[1]29	2 stations	20	[1]1	4.31	+0.89	East Hartland, Conn.	8.70	Lincoln, Me.	1.23
New Jersey	60.4	+0.1	Elizabeth	97	[1]29	Layton	21	1	3.73	−0.07	Dover	6.33	Tuckerton	0.77
New Mexico	58.0	−1.2	3 stations	100	25	2 stations	10	11	1.07	−0.18	Grady (near)	6.52	7 stations	0.00
New York	57.1	+1.4	Troy	96	30	North Lake	18	1	4.77	+1.25	Oswego	7.47	Chazy	2.07
North Carolina	64.9	−1.9	Louisburg	93	31	Mount Mitchell	22	24	4.88	+0.70	Mount Holly	8.57	Marshall	1.82
North Dakota	53.1	+0.3	Amenia	100	[1]15	Washburn	10	5	1.41	−0.99	Hillsboro	3.40	Mohall	T.
Ohio	59.1	−1.1	3 stations	95	[1]28	Millport	24	1	3.07	−0.58	Kinsman	5.61	Toledo	1.17
Oklahoma	64.7	−3.2	2 stations	100	[1]15	2 stations	30	[1]12	2.91	−1.71	Pryor	8.38	Marlow	0.67
Oregon	57.4	+4.3	Umatilla	104	13	Blitzen	11	19	0.66	−0.92	Welches	3.64	Big Eddy	0.00
Pennsylvania	59.8	+0.4	Arendtsville	98	29	2 stations	19	1	5.28	+1.38	Center Hall	12.97	Lancaster	2.33
South Carolina	68.0	−2.8	3 stations	95	[1]18	Caesar's Head	33	24	4.74	+1.10	Clemson College	10.39	Charleston	1.12
South Dakota	55.9	−0.3	Aberdeen	103	15	Camp Crook	15	21	2.02	−1.04	Watertown	8.16	Brookings	0.68
Tennessee	64.2	−2.5	Cedar Hill	97	28	Crossville	28	8	2.84	−1.39	Elkmont	7.04	Cedar Hill	1.25
Texas	69.3	−3.8	2 stations	104	[1]19	Romero	33	12	2.40	−1.31	Laredo	9.82	Clint	0.02
Utah	55.5	+0.1	St. George	100	31	Woodruff	12	[1]11	0.87	−0.41	Riverdale	2.31	Emery	0.00
Virginia	63.4	−0.4	Woodstock	97	29	Dante	30	24	5.15	+1.57	Callaville	8.26	Mount Weather	2.61
Washington	57.7	+3.3	Wahluke	103	30	Paradise Inn	19	7	1.12	−0.82	Big Four	6.91	4 stations	0.00
West Virginia	60.6	−1.0	Williamson	98	29	Bayard	23	[1]1	5.09	+1.04	Davis	9.59	Robertsburg	2.68
Wisconsin	53.5	−1.3	2 stations	92	[1]15	Big St. Germain Dam.	15	3	1.86	−1.75	Superior	3.78	Mellen	0.58
Wyoming	48.9	−0.3	Colony	96	25	Dome Lake	0	20	1.79	−0.37	Salt Creek (near)	4.76	Green River	0.13
Alaska [April]	28.8	+0.1	2 stations	75	[1]6	Fort Yukon	−22	3	1.56	−0.12	Hydahurg	14.67	McKinley Park	T.
Hawaii	72.4	+0.6	Mahukona	92	22	Kanalohuluhulu	44	[1]1	5.80	−0.18	Kailua (Mauka)	19.20	Waiopai Ranch	0.00
Porto Rico	78.7	+1.5	Dorado	97	15	Guineo Reservoir	56	16	12.00	+5.45	San Cristobal	20.09	Rio Grande	2.35

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01 or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							56,3	+1,6										77	3.91	+0.8										5.6		
Eastport	76	67	85	29.86	29.94	−0.02	48.7	+1.0	83	29	56	32	1	41	34	45	41	78	2.57	−0.4	13	6,692	s.	33	ne.	11	5	11	15	7.0	T.	0.0
Greenville, Me.	1,070	6	----	28.77	29.91	------	52.8	-----	88	20	64	24	2	41	38	----	----	----	4.02	------	15	5,091	se.	26	------	29	9	10	12	----	3.0	0.0
Portland, Me.	103	82	117	29.79	29.91	−.06	51.8	+1.5	91	29	63	33	1	47	30	48	43	70	3.84	+0.4	12	5,837	s.	26	e.	10	14	7	10	5.0	0.0	0.0
Concord	289	70	79	29.62	29.93	−.05	56.8	+2.5	92	29	69	28	2	44	44	----	----	----	2.97	0.0	14	3,685	se.	27	e.	10	15	5	11	5.0	0.0	0.0
Burlington	403	11	48	29.47	29.90	−.07	56.4	−0.1	85	20	66	31	4	46	36	----	----	----	2.20	−0.0	16	6,194	s.	36	s.	19	9	5	17	6.4	0.0	0.0
Northfield	870	12	60	28.99	29.94	−.03	53.6	+0.8	87	29	66	26	2	41	44	51	48	82	3.46	+0.7	16	4,274	s.	27	s.	2	8	9	14	6.3	0.0	0.0
Boston	125	106	165	29.80	29.94	−.04	60.3	+3.2	94	29	70	37	1	50	32	53	47	68	4.51	+1.3	10	5,238	sw.	24	nw.	3	9	12	10	5.5	0.0	0.0
Nantucket	12	14	90	29.94	29.94	−.05	54.6	+2.3	81	29	62	39	1	48	26	51	48	84	4.24	+1.4	15	10,358	sw.	36	ne.	13	8	14	9	5.2	0.0	0.0
Block Island	26	11	46	29.91	29.94	−.05	54.4	+1.6	81	30	60	38	2	48	22	51	49	86	3.79	+0.3	15	10,479	sw.	41	ne.	14	12	9	10	5.2	0.0	0.0
Providence	160	215	251	29.77	29.94	−.04	60.0	+1.5	93	29	69	35	1	50	35	53	48	69	4.07	+1.1	14	7,051	nw.	40	nw.	16	12	11	8	5.1	0.0	0.0
Hartford	159	122	----	29.76	29.94	−.04	60.0	+2.5	92	29	70	36	1	50	36	----	----	----	5.50	+1.9	13	------	s.	----	------	----	9	7	15	5.7	0.0	0.0
New Haven	106	74	153	29.83	29.94	−.05	59.4	+1.5	93	29	68	38	1	50	35	54	50	77	5.90	+2.2	16	5,672	s.	28	sw.	16	9	11	11	5.8	0.0	0.0
Middle Atlantic States							62.1	+0.1										72	4.34	+0.9										5.7		
Albany	97	107	115	29.82	29.92	−.06	60.4	+1.1	93	29	70	33	1	50	34	53	47	68	5.92	+3.0	13	1,343	s.	23	se.	2	13	8	10	4.8	T.	0.0
Binghamton	871	10	84	29.00	29.93	−.05	58.0	+0.6	89	29	70	28	1	46	41	----	----	----	4.77	+1.5	16	3,568	nw.	19	w.	16	8	5	18	6.4	T.	0.0
New York	314	414	454	29.60	29.93	−.06	60.4	−0.2	89	30	68	40	1	52	24	53	48	70	3.93	+0.7	13	9,110	s.	42	w.	16	8	12	11	5.9	0.0	0.0
Bellefonte	1,050	5	36	28.82	29.92	------	57.7	----	89	28	70	23	1	46	44	52	47	71	8.03	------	17	------	sw.	34	s.	30	4	13	14	6.7	0.0	0.0
Harrisburg	374	94	104	29.55	29.95	−.03	62.3	+0.5	91	29	72	37	1	53	33	54	48	65	3.75	+0.3	15	4,407	w.	27	s.	30	7	16	8	5.3	0.0	0.0
Philadelphia	114	123	367	29.83	29.95	−.04	64.2	+1.3	91	30	73	43	1	55	30	55	50	66	4.44	+1.2	12	8,396	sw.	35	sw.	16	7	12	12	6.3	0.0	0.0
Reading	325	81	98	29.59	29.94	------	62.6	+0.1	91	29	73	35	1	52	34	54	48	64	3.66	0.0	14	4,050	se.	20	se.	22	8	14	9	5.7	0.0	0.0
Scranton	805	111	119	29.08	29.93	−.05	59.0	+0.2	91	29	72	30	1	48	40	53	47	65	4.03	+0.8	16	4,006	sw.	26	sw.	20	9	12	10	5.5	0.0	0.0
Atlantic City	52	37	172	29.89	29.95	−.03	58.0	−0.1	83	16	64	41	5	52	26	54	51	80	1.43	−1.6	13	10,990	s.	40	ne.	13	10	11	10	5.4	0.0	0.0
Cape May	17	13	49	------	------	------	59.2	+0.6	82	16	67	36	5	51	27	55	52	84	2.76	−0.2	14	------	se.	----	------	----	6	13	12	----	0.0	0.0
Sandy Hook	22	10	55	29.90	29.92	------	58.5	------	89	29	66	43	1	52	30	54	51	81	4.03	+0.3	13	8,307	s.	34	sw.	20	8	12	11	5.5	0.0	0.0
Trenton	190	159	183	29.74	29.94	------	61.8	+0.7	92	30	72	38	1	51	34	56	52	75	4.00	+0.9	13	6,066	sw.	30	w.	16	8	13	10	6.0	0.0	0.0
Baltimore	123	100	215	29.80	29.93	−.06	65.2	+0.8	88	30	74	43	1	57	30	57	51	66	5.80	+2.3	12	6,960	se.	36	sw.	16	9	9	13	6.1	0.0	0.0
Washington	112	62	85	29.82	29.94	−.06	65.1	+1.4	92	30	75	40	1	55	34	50	51	65	4.84	+1.1	12	3,951	s.	24	nw.	24	7	13	11	5.3	0.0	0.0
Cape Henry	18	8	54	29.93	29.95	------	63.9	−0.3	88	16	72	47	4	56	30	59	56	78	3.75	+0.2	13	6,958	sw.	31	nw.	23	8	13	10	5.5	0.0	0.0
Lynchburg	681	153	188	29.21	29.94	−.06	65.0	−2.3	92	29	76	41	5	54	35	58	54	72	5.93	+2.3	13	4,262	w.	40	nw.	22	11	10	10	5.3	0.0	0.0
Norfolk	91	170	205	29.87	29.97	−.03	66.0	−0.2	88	29	75	46	24	57	29	58	54	72	4.62	+0.8	15	7,988	s.	34	nw.	22	9	13	9	5.4	0.0	0.0
Richmond	144	11	52	29.80	29.96	−.03	65.5	−1.0	88	29	76	41	5	55	31	59	55	78	5.64	+1.8	15	4,778	sw.	39	w.	9	10	8	13	5.5	0.0	0.0
Wytheville	2,304	49	55	27.60	29.94	−.05	59.2	−2.2	87	29	70	41	9	49	35	53	48	72	4.85	+1.2	18	3,718	w.	22	nw.	22	9	11	11	5.7	0.0	0.0
South Atlantic States							68.5	−1.7										71	4.14	+0.6										4.9		
Asheville	2,253	89	104	27.65	29.97	−.02	61.8	−0.8	88	29	73	36	24	50	38	54	49	69	2.20	−1.2	13	5,225	nw.	26	nw.	23	9	16	6	5.0	0.0	0.0
Charlotte	779	55	62	29.14	29.96	−.03	67.2	−1.7	90	31	78	43	24	57	29	58	53	66	6.53	+2.9	13	2,761	sw.	19	nw.	22	10	10	11	5.4	0.0	0.0
Greensboro	886	6	56	29.02	29.98	------	64.6	------	88	29	76	38	24	52	39	57	53	74	5.97	------	12	5,214	sw.	35	sw.	7	8	13	10	5.7	0.0	0.0
Hatteras	11	5	50	29.96	29.97	−.03	67.1	−1.6	79	16	74	54	24	60	22	62	66	82	4.35	+0.6	12	7,716	sw.	30	nw.	23	18	7	6	3.8	0.0	0.0
Raleigh	376	103	146	29.56	29.96	−.03	66.8	−1.7	88	29	77	41	5	56	31	59	54	69	6.16	+2.4	9	5,177	sw.	32	se.	7	9	12	10	5.4	0.0	0.0
Wilmington	78	81	91	29.91	29.99	−.02	68.7	−2.1	86	16	78	48	24	60	26	62	59	75	3.62	+0.2	11	4,777	sw.	20	w.	22	12	11	8	4.6	0.0	0.0
Charleston	48	11	92	29.93	29.98	−.03	71.4	−1.3	88	17	79	53	24	64	23	64	61	74	1.12	−1.9	7	6,861	s.	32	e.	4	12	9	10	5.1	0.0	0.0
Columbia, S. C.	351	41	57	29.60	29.97	−.03	68.9	−3.0	90	18	79	46	24	59	31	60	54	66	3.75	+0.7	13	4,392	s.	19	w.	11	10	16	5	4.9	0.0	0.0
Due West	711	10	55	29.23	30.00	------	67.0	------	89	31	78	43	24	56	31	----	----	----	3.17	------	13	5,534	sw.	31	w.	31	12	11	8	4.9	0.0	0.0
Greenville, S. C.	1,039	139	146	28.88	29.96	------	66.2	−1.0	88	18	76	46	8	57	29	57	51	04	5.73	+1.7	14	5,551	s.	36	w.	22	13	10	8	4.6	0.0	0.0
Augusta	182	62	77	29.76	29.95	−.04	70.3	−2.1	91	26	81	48	24	59	36	63	59	73	3.51	+0.5	15	3,542	nw.	20	n.	26	11	13	7	4.3	0.0	0.0
Savannah	65	150	194	29.90	29.97	−.03	72.0	−1.4	91	22	81	52	24	63	28	64	60	73	1.88	−1.1	8	7,236	s.	28	s.	7	12	6	13	5.0	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	−.02	73.2	−1.8	89	22	81	57	14	65	23	65	61	72	5.93	+1.9	11	6,954	s.	29	nw.	27	13	8	10	4.8	0.0	0.0
Florida Peninsula							77.1	−0.1										73	3.33	−0.9										4.8		
Key West	22	10	64	29.93	29.95	−.02	78.0	−0.5	87	12	84	69	9	73	16	72	69	75	2.41	−1.1	4	6,041	e.	25	w.	13	12	15	4	4.2	0.0	0.0
Miami	25	124	168	29.94	29.97	−.02	77.0	+0.6	87	12	82	59	15	72	20	70	66	71	4.34	−1.9	14	6,269	ne.	26	nw.	14	8	12	11	5.5	0.0	0.0
Tampa	35	79	197	29.94	29.98	−.01	75.8	−0.5	89	1	84	60	25	67	26	68	64	73	3.24	+0.2	9	6,337	e.	30	n.	11	12	11	8	4.7	0.0	0.0
Titusville	44	5	----	29.94	29.99	------	75.8	------	92	11	85	56	14	67	27	----	----	----	3.42	------	9	------	ne.	----	------	----	14	9	8	4.8	0.0	0.0
East Gulf States							69.6	−2.8										69	2.95	−0.9										4.3		
Atlanta	1,173	190	198	28.75	29.98	−.01	66.6	−3.3	89	30	76	46	24	57	29	57	50	61	2.77	−0.7	9	6,650	w.	25	w.	22	14	7	10	4.6	0.0	0.0
Macon	370	78	87	29.58	29.97	−.02	69.2	−3.1	92	31	81	46	24	58	37	60	54	62	4.96	+2.0	9	3,796	s.	19	s.	19	14	9	8	4.4	0.0	0.0
Thomasville	273	49	103	29.68	29.97	−.02	72.4	−1.6	92	31	84	53	13	61	29	63	59	69	4.05	+0.4	8	4,469	sw.	24	s.	4	8	18	5	4.6	0.0	0.0
Apalachicola	36	11	51	29.94	29.98	------	71.8	------	88	27	79	55	24	64	23	66	62	74	1.16	−2.2	7	5,121	sw.	35	e.	27	20	7	4	2.7	0.0	0.0
Pensacola	56	149	185	29.92	29.98	−.01	71.0	−2.9	85	31	77	54	13	65	19	64	61	73	1.83	−1.5	7	7,652	sw.	29	e.	27	11	17	3	4.3	0.0	0.0
Anniston	741	9	57	29.21	30.00	+.01	66.6	−1.8	91	27	79	40	24	54	38	----	----	----	3.29	−0.6	10	2,941	nw.	14	w.	10	17	7	7	4.2	0.0	0.0
Birmingham	700	11	48	29.22	29.98	.00	67.6	−3.5	90	27	79	47	13	57	30	59	54	68	2.72	−1.2	9	4,019	n.	23	s.	19	13	11	7	4.5	0.0	0.0
Mobile	57	125	161	29.91	29.98	−.01	71.6	−2.8	91	27	80	52	13	63	26	65	61	76	3.63	−0.7	9	6,097	sw.	33	nw.	20	10	12	9	4.8	0.0	0.0
Montgomery	223	100	112	29.73	29.98	−.01	70.0	−3.4	90	27	80	50	24	60	28	60	55	64	2.55	−1.3	9	4,169	w.	27	se.	20	12	12	7	4.6	0.0	0.0
Corinth	469	6	----	------	------	------	67.2	------	95	27	79	43	8	56	38	----	----	----	3.44	------	9	------	se.	----	------	----	11	15	5	----	0.0	0.0
Meridian	375	87	95	29.58	29.97	−.01	68.6	−2.7	91	27	80	47	24	58	34	60	54	64	2.67	−1.6	9	3,629	sw.	23	w.	11	13	13	5	4.3	0.0	0.0
Vicksburg	247	65	73	29.72	30.00	+.03	69.0	−3.9	92	28	78	51	12	59	26	62	58	71	3.29	−1.0	7	4,119	nw.	21	w.	11	14	11	6	3.9	0.0	0.0
New Orleans	53	76	84	29.92	29.97	.00	73.4	−2.0	90	30	82	58	13	65	24	67	64	77	2.48	−2.1	9	3,634	sw.	17	nw.	20	11	15	5	4.3	0.0	0.0
West Gulf States							69.8	−3.6										72	1.96	−2.1										5.0		
Shreveport	249	77	93	29.71	29.98	+.03	69.0	−4.6	90	28	79	45	7	59	28	62	58	73	1.17	−3.0	8	3,893	s.	16	w.	11	10	14	7	4.9	0.0	0.0
Bentonville	1,303	11	44	28.58	29.94	+.01	61.4	−5.0	89	16	72	37	7	51	34	----	----	----	5.42	------	9	3,170	s.	17	w.	9	21	4	6	----	0.0	0.0
Fort Smith	457	79	94	29.47	29.95	+.02	65.5	−4.1	90	16	76	41	7	56	31	58	52	66	4.35	−0.5	11	5,259	e.	36	w.	29	12	10	9	5.1	0.0	0.0
Little Rock	357	136	153	29.59	29.96	+.01	66.0	−4.3	88	16	75	46	7	57	27	58	52	64	2.07	−2.7	11	6,328	sw.	26	sw.	5	9	13	9	5.5	0.0	0.0
Austin	605	136	148	29.32	29.95	------	71.6	−3.0	90	15	82	48	7	61	36	63	58	67	0.58	−4.1	5	5,600	s.	26	ne.	11	8	15	8	5.1	0.0	0.0
Brownsville	57	83	100	29.87	29.93	------	75.3	−3.3	88	6	82	62	7	68	22	69	67	82	0.86	−1.4	11	6,962	se.	32	nw.	7	8	14	9	5.4	0.0	0.0
Corpus Christi	20	11	78	29.93	29.95	+.05	73.6	−2.6	85	31	79	57	7	68	23	68	66	82	2.72	−0.5	10	8,148	se.	37	nw.	20	6	13	12	6.3	0.0	0.0
Dallas	512	220	227	29.43	29.98	------	67.4	------	90	15	76	44	7	58	32	----	----	----	3.01	−1.5	7	8,308	se.	31	w.	5	13	11	7	4.0	0.0	0.0
Fort Worth	670	106	114	29.25	29.96	+.05	68.5	−3.8	91	15	78	45	7	59	32	59	54	65	2.42	−2.2	7	5,691	nw.	28	se.	21	8	9	14	5.8	0.0	0.0
Galveston	54	106	114	29.94	30.00	+.06	71.8	−3.0	83	3	76	56	7	67	17	66	64	80	3.14	−0.3	5	6,712	se.	26	se.	19	6	17	8	5.3	0.0	0.0
Groesbeck	461	11	56	29.49	29.97	------	67.8	------	85	15	77	45	7	58	30	----	----	----	3.03	−1.0	8	6,745	n.	30	n.	21	12	13	6	4.6	0.0	0.0
Houston	138	292	314	29.84	29.99	------	72.1	−3.4	85	4	80	52	7	64	25	----	----	----	0.37	−4.1	5	7,412	se.	30	n.	11	13	8	10	5.1	0.0	0.0
Palestine	510	64	72	29.46	29.99	+.06	68.5	−4.2	86	25	78	44	7	59	28	61	57	71	2.16	−2.4	8	4,691	s.	20	nw.	12	13	11	7	4.6	0.0	0.0
Port Arthur	34	58	66	29.95	29.99	------	72.2	------	88	29	80	53	12	65	23	----	----	----	1.20	−2.9	6	4,898	s.	23	n.	20	17	6	8	4.2	0.0	0.0
San Antonio	693	242	301	29.22	29.93	+.03	72.5	−2.6	90	14	82	52	7	63	30	63	58	66	1.36	−1.8	11	8,116	n.	34	n.	19	8	19	4	4.9	0.0	0.0
Taylor	571	38	51	29.40	29.99	+.08	71.0	−3.3	90	15	82	45	7	60	37	----	----	----	0.97	−3.0	6	5,799	s.	23	n.	6	11	16	4	4.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							62.2	−2.7										66	3.28	−0.5										5.8		
Chattanooga	762	190	215	29.15	29.95	−0.04	66.7	−2.1	90	27	77	41	8	57	32	57	50	59	1.77	−2.0	8	5,809	sw.	27	sw.	10	11	14	6	6.0	0.0	0.0
Knoxville	995	102	111	28.92	29.96	−.03	66.0	−1.2	91	29	77	41	24	55	31	57	51	64	3.71	0.0	12	4,329	sw.	31	s.	11	7	15	9	5.8	0.0	0.0
Memphis	399	76	97	29.53	29.95	−.01	66.4	−4.2	91	28	75	45	7	58	27	57	51	62	2.30	−1.9	11	5,914	sw.	28	sw.	10	12	8	11	5.0	0.0	0.0
Nashville	546	168	191	29.40	29.98	.00	64.8	−3.4	91	28	74	42	8	55	32	57	51	65	1.92	−2.0	11	6,290	nw.	36	nw.	22	8	14	9	5.5	0.0	0.0
Lexington	989	193	230	28.92	29.98	−.01	61.2	−3.[illegible]	88	29	70	39	3	52	34				1.13	−2.7	9	8,438	sw.	35	sw.	20	13	6	12	5.2	0.0	0.0
Louisville	525	188	234	29.38	29.96	−.02	62.4	−4.2	89	29	72	40	8	53	32	55	50	67	1.94	−1.8	9	7,010	s.	36	nw.	19	8	9	14	5.9	0.0	0.0
Evansville	431	76	116	29.48	29.95	−.02	62.8	−3.9	90	17	72	38	7	53	29	56	51	68	2.37	−1.5	13	6,295	s.	36	s.	19	9	10	12	5.9	0.0	0.0
Indianapolis	822	194	230	29.05	29.94	−.03	59.4	−3.5	87	28	69	37	7	50	30	51	44	63	2.51	−1.4	12	7,668	sw.	27	sw.	18	8	9	14	6.1	0.0	0.0
Royal Center	736	11	55	29.13	29.93		55.8		87	28	67	30	3	44	36				3.81	−0.2	11	6,846	s.	26	se.	5	12	5	14	5.3	0.0	0.0
Terre Haute	575	96	129	29.32	29.93		60.2		89	28	70	38	7	50	34	53	48	69	3.24	−0.6	8	6,197	s.	30	sw.	16	8	8	15	6.2	0.0	0.0
Cincinnati	627	11	51	29.27	29.95	−.04	60.6	−2.5	89	29	71	37	3	50	33	53	48	67	4.47	+0.8	12	4,433	sw.	22	sw.	6	9	9	13	6.1	0.0	0.0
Columbus	822	216	230	29.07	29.94	−.04	59.8	−2.5	89	28	70	38	1	50	30	52	46	64	2.96	−0.6	14	7,046	s.	32	w.	2	7	14	10	5.9	0.0	0.0
Dayton	899	137	173	28.99	29.94		59.6	−3.0	87	29	69	37	3	50	33	53	47	65	2.11	−1.5	15	5,693	sw.	26	sw.	20	7	15	9	6.1	0.0	0.0
Elkins	1,947	59	67	27.94	29.97	−.03	58.0	−1.2	86	28	70	29	4	46	45	51	47	73	7.90	+3.8	19	3,498	w.	25	nw.	2	4	9	18	7.1	0.0	0.0
Parkersburg	637	77	82	29.31	29.97	−.02	62.1	−1.7	92	28	72	38	4	52	38	54	48	65	4.82	+1.4	17	3,431	nw.	24	nw.	2	9	7	15	6.3	0.0	0.0
Pittsburgh	842	353	410	29.04	29.93	−.06	60.8	−1.6	88	29	71	36	4	50	37	53	48	66	5.46	+2.2	19	6,421	sw.	33	nw.	23	6	13	12	6.1	0.0	0.0
Lower Lake Region							57.5	0.0										67	3.45	+0.2										5.5		
Buffalo	767	247	280	29.08	29.90	−.07	55.6	+1.0	83	6	64	34	1	48	39	49	43	69	2.74	−0.4	18	9,233	sw.	48	w.	30	10	11	10	5.4	0.0	0.0
Canton	448	10	61	29.41	29.88		55.7	−0.5	85	20	65	27	1	46	40				3.53	+0.5	18	6,159	sw.	36	sw.	19	8	10	13	5.9	0.0	0.0
Ithaca	836	74	100	28.99	29.91		58.4	+0.9	92	29	70	30	1	47	40	51	46	68	4.48	+1.1	15	5,992	nw.	30	se.	7	10	8	13	5.8	0.8	0.0
Oswego	335	71	85	29.54	29.90	−.07	55.2	0.0	86	28	64	32	1	47	39	50	45	71	7.47	+4.4	13	5,747	w.	24	nw.	30	7	10	14	6.2	T.	0.0
Rochester	523	86	102	29.35	29.92	−.05	58.8	+1.7	89	28	68	32	1	49	40	50	44	65	5.32	+2.4	15	5,465	sw.	27	w.	20	9	9	13	5.8	T.	0.0
Syracuse	596	65	79	29.28	29.92	−.06	59.2	+1.9	90	29	68	34	1	50	38				4.42	+1.4	15	4,396	s.	20	s.	16	11	7	13	5.8	T.	0.0
Erie	714	130	166	29.15	29.92	−.06	57.2	+0.4	86	18	66	33	1	49	38	51	46	69	2.83	−0.6	16	8,642	w.	38	s.	19	13	8	10	4.9	0.0	0.0
Cleveland	762	267	337	29.11	29.93	−.05	57.5	−0.4	86	28	65	36	1	50	36	50	44	65	2.36	−0.8	16	8,891	n.	36	nw.	23	8	10	13	6.0	0.0	0.0
Sandusky	629	5	67	29.26	29.94	−.04	58.4	−0.8	90	28	68	36	24	49	40				2.10	−1.0	15	5,436	sw.	22	sw.	16	7	11	13	5.8	0.0	0.0
Toledo	628	208	243	29.25	29.93	−.04	58.4	−1.0	88	28	68	37	3	49	38	50	43	64	1.17	−2.3	15	8,561	sw.	31	sw.	19	11	12	8	4.7	0.0	0.0
Fort Wayne	856	100	119	29.01	29.93		57.1	−3.1	88	28	68	36	24	46	38	51	46	68	2.00	−1.8	13	6,350	sw.	25	nw.	2	12	7	12	5.2	0.0	0.0
Detroit	730	218	258	29.15	29.94	−.03	58.4	+0.4	90	28	69	39	1	48	42	50	45	68	2.32	−0.9	13	6,014	sw.	28	sw.	20	14	10	7	4.2	0.0	0.0
Upper Lake Region							52.3	−0.5										71	2.88	−0.3										5.8		
Alpena	609	13	92	29.24	29.91	−.06	52.0	+1.5	92	28	62	30	3	42	39	47	42	73	2.74	−0.3	12	7,068	se.	27	nw.	2	11	8	12	5.6	T.	0.0
Escanaba	612	54	60	29.24	29.91	−.06	49.0	−0.6	87	15	56	26	30	42	30	44	39	71	3.06	+0.1	9	6,595	s.	30	n.	2	11	7	13	5.6	T.	0.0
Grand Haven	632	54	89	29.23	29.91	−.05	51.6	−3.9	79	28	60	31	3	43	32	47	42	72	2.88	−0.3	11	6,867	w.	26	sw.	18	12	2	17	6.0	0.0	0.0
Grand Rapids	707	70	244	29.15	29.92	−.05	56.0	−2.0	91	28	66	31	3	46	35	49	42	66	3.23	−0.2	14	7,066	sw.	38	sw.	18	11	5	15	6.2	0.0	0.0
Houghton	668	64	99	29.17	29.90	−.07	49.2	−0.3	87	15	59	28	3	40	41				2.80	−0.3	13	6,427	w.	33	nw.	15	8	9	14	6.1	T.	0.0
Lansing	878	6	88	28.97	29.91		55.2	−1.7	87	28	66	30	3	44	38	50	46	75	3.71	+0.3	14	5,762	s.	21	nw.	2	10	9	12	5.4	0.0	0.0
Ludington	637	60	66	29.22	29.91		50.0	−2.2	74	27	57	32	3	43	26	46	42	76	2.61	−0.4	11	6,314	u.	26	s.	1	14	4	13	5.1	0.0	0.0
Marquette	734	77	111	29.10	29.90	−.07	50.0	+1.0	88	15	59	30	3	41	44	44	39	71	1.65	−1.3	14	7,052	nw.	34	sw.	1	8	5	18	6.9	T.	0.0
Port Huron	638	70	120	29.22	29.91	−.06	55.0	−0.2	86	29	64	34	1	46	39	48	43	69	1.87	−1.1	14	7,535	s.	27	w.	16	10	12	9	5.2	0.0	0.0
Sault Sainte Marie	614	11	52	29.22	29.92	−.03	50.7	+1.7	87	28	61	29	3	40	35	45	40	72	3.49	+0.5	13	5,200	nw.	24	nw.	25	8	15	8	5.2	0.1	0.0
Chicago	673	7	131	29.20	29.92	−.04	55.6	−1.9	87	28	63	40	7	48	29	49	44	71	5.08	+1.5	9	6,654	ne.	27	sw.	18	12	7	12	5.3	0.0	0.0
Green Bay	617	109	141	29.23	29.88	−.07	54.4	−0.5	84	28	64	30	3	44	34	47	41	67	1.08	−2.4	10	6,917	s.	30	ne.	16	5	9	17	7.0	0.0	0.0
Milwaukee	681	125	221	29.18	29.91	−.05	53.0	−1.1	85	28	61	36	3	45	33	47	42	71	1.70	−1.6	9	8,216	n.	36	w.	18	11	8	12	5.6	T.	0.0
Duluth	1,133	5	47	28.71	29.93	−.03	50.4	+3.1	88	15	60	30	6	40	37	43	38	69	4.51	+1.3	11	7,806	ne.	36	ne.	10	12	6	13	5.4	T.	0.0
North Dakota							53.6	−0.5										53	1.50	−1.0										4.9		
Moorhead	940	50	58	28.89	29.90	−.04	53.2	−1.9	94	15	66	24	7	41	41	45	36	57	1.95	−0.9	9	6,823	n.	33	nw.	27	11	7	13	5.9	1.2	0.0
Bismarck	1,674	8	57	28.14	29.92	.00	54.4	−0.1	93	25	68	23	20	41	42	44	34	53	1.94	−0.4	8	7,316	n.	36	w.	18	15	9	7	4.3	0.1	0.0
Devils Lake	1,478	11	44	28.34	29.92	−.02	51.4	−1.2	86	14	64	24	5	38	40	43	34	57	1.42	−0.6	11	7,707	n.	42	ne.	27	13	7	11	5.3	0.5	0.0
Ellendale	1,457	10	56	28.36	29.93		52.2		93	15	65	22	6	39	42				1.71	−1.4	8	11,077	n.	46	n.	27	14	4	13	5.4	T.	0.0
Grand Forks	833	12	67				52.4		92	26	66	22	6	39	43	44			2.87		8		nw.	38	nw.	1	19	3	9		0.9	0.0
Williston	1,878	41	48	27.95	29.92	−.01	55.2	+1.2	93	25	69	25	6	41	44	43	31	46	0.47	−1.6	4	6,011	n.	39	w.	18	17	8	6	3.5	0.5	0.0
Upper Mississippi Valley							58.5	−3.0										66	2.91	−1.1										5.7		
Minneapolis	918	102	208	28.83	29.87		56.1	−1.6	91	15	66	30	6	46	34				1.35	−2.3	8	8,157	n.	39	nw.	15	8	5	18	6.4	T.	0.0
St. Paul	837	114	149	28.99	29.89	−.05	56.2	−1.7	90	15	67	32	6	46	33				1.08	−2.2	9	6,372	ne.	32	nw.	15	12	7	12	5.5	0.0	0.0
La Crosse	714	11	48	29.12	29.89	−.05	56.0	−3.3	88	27	67	31	23	45	37	49	42	64	2.15	−1.6	10	3,008	nw.	16	sw.	15	9	8	14	5.8	0.0	0.0
Madison	974	70	78	28.86	29.90	−.06	54.9	−2.7	84	27	64	34	7	46	36	48	42	66	1.74	−2.1	12	5,264	s.	23	ne.	16	11	5	15	6.1	0.0	0.0
Wausau	1,247	4	62	28.57	29.91		54.0		84	15	66	28	23	42	38				0.61	−3.1	8	4,417	n.	21	sw.	1	14	6	11	5.3	0.0	0.0
Charles City	1,015	10	51	28.84	29.92	−.02	55.4	−2.4	90	27	67	31	6	44	39	48	40	61	2.73	−1.6	10	4,396	nw.	22	s.	26	13	7	11	4.7	0.0	0.0
Davenport	606	71	79	29.26	29.91	−.04	58.4	−2.9	88	27	68	35	7	48	37	50	43	62	3.21	−0.7	12	6,223	nw.	30	sw.	5	11	7	13	5.7	0.0	0.0
Des Moines	861	5	99	29.01	29.91	−.02	59.2	−2.1	90	27	71	28	7	48	34	50	43	60	2.68	−1.9	8	6,814	nw.	34	s.	24	10	9	12	5.0	0.0	0.0
Dubuque	700	81	96	29.16	29.90	−.05	56.8	−3.5	87	27	66	34	23	47	37	49	43	65	2.00	−2.2	9	3,889	s.	20	s.	24	10	6	15	6.0	0.0	0.0
Keokuk	614	64	78	29.26	29.92	−.01	59.4	−4.4	88	16	69	32	7	50	32	52	46	64	4.27	+0.3	12	4,363	sw.	19	w.	20	11	9	11	5.4	0.0	0.0
Cairo	358	87	93	29.56	29.94	−.02	64.0	−4.4	91	28	73	43	7	55	29	57	53	72	2.99	−0.7	11	5,828	s.	28	w.	9	3	11	17	6.9	0.0	0.0
Peoria	609	11	45	29.27	29.93	−.03	58.2	−3.5	87	27	68	36	7	48	33	52	47	70	5.14	+1.1	12	3,811	s.	18	w.	29	13	6	12	5.0	0.0	0.0
Springfield, Ill	636	5	191	29.24	29.92	−.03	60.6	−2.6	91	28	71	35	7	50	33	54	50	72	4.87	+0.5	12	7,762	sw.	34	s.	24	11	10	10	5.6	0.0	0.0
Hannibal	534	74	109	29.35	29.92	−.02	60.1	−3.5	88	27	70	35	7	51	31				5.26	+0.9	14	5,368	sw.	26	sw.	24	8	11	12	5.7	0.0	0.0
St. Louis	568	265	303	29.33	29.93	−.02	62.8	−4.1	91	16	72	40	6	54	31	54	49	65	3.61	−0.7	12	8,235	sw.	36	sw.	18	13	7	11	5.2	0.0	0.0
Missouri Valley							58.9	−2.5										60	3.44	−0.5										4.7		
Columbia, Mo	784	6	84	29.10	29.93	−.01	60.4	−3.9	89	17	71	33	7	50	35				6.45	+2.0	13	4,775	s.	22	w.	29	12	7	12	5.5	0.0	0.0
Kansas City	963	161	181	28.90	29.93	+.01	62.0	−2.8	94	16	71	38	6	53	28	54	48	64	5.99	+1.3	13	6,595	s.	29	sw.	29	15	6	10	4.5	0.0	0.0
St. Joseph	967	11	49	28.89	29.92		60.8		91	16	71	36	6	50	34	53	47	67	4.13	−0.1	10	5,388	nw.	23	nw.	9	16	6	9	4.3	0.0	0.0
Springfield, Mo	1,324	98	104	28.56	29.96	+.03	59.8	−4.7	90	16	68	38	7	51	28	53	47	67	3.65	−1.5	13	6,826	s.	30	w.	9	18	8	5	3.3	0.0	0.0
Iola	984	11	50	28.90	29.94	+.02	61.3	−3.9	93	16	72	37	7	50	34				3.67	−1.0	9	4,204	s.	19	nw.	10	12	7	12	5.5	0.0	0.0
Topeka	987	92	107				61.0	−3.3	95	16	71	38	20	51	31				2.03	−2.4	9	6,294	nw.	23	nw.	11	16	4	11	4.5	0.0	0.0
Lincoln	1,189	11	81	28.66	29.92	+.01	58.7	−3.0	91	26	70	34	6	48	36	51	45	64	6.41	+2.3	11	7,102	n.	43	sw.	27	11	10	10	5.4	0.0	0.0
Omaha	1,105	115	122	28.76	29.93	+.01	59.8	−2.6	92	17	70	33	6	50	31	50	42	59	3.26	−0.5	10	5,946	nw.	29	nw.	27	16	7	8	4.4	0.0	0.0
Valentine	2,598	47	54	27.25	29.95	+.05	55.2	−1.0	95	23	69	25	21	41	45	46	37	56	1.01	−1.8	6	7,248	n.	32	n.	9	13	9	9	5.1	T.	0.0
Sioux City	1,135	94	164	28.70	29.91	−.01	58.4	−2.0	91	24	70	30	6	47	34	49	40	58	2.71	−1.3	10	8,809	nw.	41	s.	26	11	8	12	5.5	T.	0.0
Huron	1,306	59	74	28.54	29.94	+.02	55.2	−1.2	96	15	68	24	6	42	40	46	37	55	1.85	−1.1	7	7,441	n.	31	s.	23	16	8	7	4.0	0.0	0.0
Pierre	1,572	70	75	28.26	29.91	.00	57.2	−0.8	97	15	70	25	21	44	43	47	37	53	2.11	−0.4	6	7,115	nw.	32	s.	26	11	13	7	4.8	T.	0.0
Yankton	1,233	49	57	28.63	29.94	+.02	58.1	−1.3	91	15	70	29	6	46	41				1.48	−2.4	7	5,862	nw.	30	s.	26	14	10	7	4.3	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							53.6	+0.9										52	1.23	−1.2										5.5		
Billings	3,140	5	----	----	----	----	56.0	----	95	25	74	21	21	38	54	----	----	----	0.67	----	6	----	nw.	----	----	----	9	13	9	----	0.0	0.0
Havre	2,505	11	67	27.34	29.96	+0.06	56.4	+3.0	95	14	71	31	5	42	48	44	31	46	0.21	−1.8	4	6,242	nw.	35	sw.	16	9	11	11	5.9	T.	0.0
Helena	4,124	89	113	25.80	29.97	+.04	54.0	+2.4	84	13	67	30	21	41	42	42	31	49	1.09	−1.2	10	5,719	sw.	34	sw.	17	4	12	15	6.7	0.8	0.0
Kalispell	2,973	48	56	26.93	29.96	+.08	54.6	+3.2	84	13	68	30	21	42	39	44	34	53	0.52	−0.9	6	4,593	nw.	31	sw.	6	5	12	14	6.3	0.0	0.0
Miles City	2,371	48	55	27.44	29.98	+.07	57.9	+1.2	95	14	72	30	20	44	43	44	30	41	0.59	−1.6	5	4,871	s.	32	nw.	18	12	13	6	4.5	T.	0.0
Rapid City	3,259	50	58	26.58	29.98	+.08	54.8	+0.8	94	25	68	27	21	42	46	45	35	51	1.06	−2.5	8	6,825	n.	37	n.	8	11	14	6	4.8	T.	0.0
Cheyenne	6,088	84	101	24.01	29.96	+.11	48.6	−1.7	82	26	61	22	20	36	44	39	30	54	1.57	−0.9	9	8,266	w.	40	w.	7	6	10	15	6.5	0.1	0.0
Lander	5,372	60	68	24.65	29.98	+.10	51.8	+0.6	83	15	65	28	8	39	47	41	31	54	2.20	−0.1	11	4,231	sw.	36	sw.	26	11	13	7	4.9	0.2	0.0
Sheridan	3,790	10	47	26.10	29.98	----	52.8	----	90	25	68	24	20	38	49	43	34	57	2.38	−0.3	9	3,671	nw.	32	nw.	7	6	17	8	5.5	0.6	0.0
Yellowstone Park	6,241	11	48	----	30.00	+.09	46.4	−1.0	75	25	59	22	8	34	41	----	----	55	1.61	−0.6	12	4,835	n.	29	sw.	16	4	13	14	----	5.5	0.0
North Platte	2,821	11	51	27.03	29.94	+.06	58.1	−0.6	95	15	72	28	20	44	43	48	39	56	0.47	−2.3	6	5,969	nw.	31	nw.	9	13	11	7	4.7	0.0	0.0
Middle Slope							59.9	−2.6										60	2.59	−0.8										4.7		
Denver	5,292	106	113	24.74	29.97	+.13	55.0	−1.2	86	26	66	30	20	43	42	43	33	55	3.45	+1.2	15	5,112	s.	35	n.	5	6	16	9	5.5	7.2	0.0
Pueblo	4,685	80	86	25.29	29.91	+.11	57.9	−1.2	90	15	71	32	22	44	45	45	35	53	2.58	+1.0	10	4,709	nw.	30	w.	3	12	13	6	4.9	T.	0.0
Concordia	1,392	50	58	28.50	29.97	+.06	60.0	−3.2	91	24	70	33	20	50	32	52	47	66	3.83	−0.4	9	5,976	s.	30	nw.	9	13	9	9	4.8	0.0	0.0
Dodge City	2,509	88	100	27.39	29.98	+.11	59.5	−4.0	92	15	71	31	22	48	36	51	45	64	2.14	−0.8	7	9,002	s.	43	nw.	8	18	8	5	3.4	T.	0.0
Wichita	1,358	139	158	28.52	29.94	+.04	61.6	−3.5	91	16	71	38	22	52	29	53	47	62	2.37	−2.1	8	8,375	s.	34	sw.	17	12	11	8	4.9	0.0	0.0
Oklahoma City	1,214	10	47	28.68	29.95	+.06	65.4	−2.3	92	25	75	42	22	56	32	56	50	63	1.18	−3.7	7	6,871	s.	26	n.	8	13	5	13	4.9	0.0	0.0
Southern Slope							66.7	−3.9										60	2.76	+0.1										4.4		
Abilene	1,738	10	52	28.16	29.95	+.08	68.4	−3.6	93	15	80	41	7	57	34	57	49	58	1.14	−2.8	5	6,808	s.	27	sw.	21	10	12	9	5.0	0.0	0.0
Amarillo	3,676	10	49	26.26	29.94	+.10	61.4	−2.7	93	25	73	37	22	49	39	51	44	60	3.11	+0.3	13	6,291	se.	27	w.	4	15	8	8	4.1	0.0	0.0
Del Rio	914	64	71	28.90	29.88	+.01	72.2	−4.8	91	18	82	51	12	62	33	63	58	68	6.10	+3.2	10	5,834	se.	46	w.	4	9	14	8	5.2	0.0	0.0
Roswell	3,566	75	85	26.34	29.90	+.08	65.0	−4.4	93	25	78	43	22	52	39	52	42	52	0.70	−0.4	3	5,422	s.	44	nw.	4	16	13	2	3.3	0.0	0.0
Southern Plateau							68.2	+2.8										39	0.10	−0.3										2.0		
El Paso	3,778	152	175	26.13	29.83	+.05	72.3	+0.8	96	25	85	51	11	59	33	53	34	32	0.06	−0.3	2	6,239	e.	32	nw.	18	22	9	0	2.2	0.0	0.0
Albuquerque	4,972	51	66	25.06	29.85	----	62.0	----	86	25	76	38	12	48	36	47	33	44	0.99	----	5	4,208	sw.	23	se.	30	19	7	5	3.1	0.0	0.0
Santa Fe	7,013	38	53	23.25	29.85	+.04	55.0	−0.7	78	24	68	29	11	42	37	41	27	42	0.46	−0.8	6	4,462	sw.	20	sw.	7	19	9	3	3.3	T.	0.0
Flagstaff	6,907	10	59	23.36	29.86	+.08	51.9	+1.2	80	31	69	26	20	35	44	40	----	53	0.33	----	3	5,708	nw.	30	nw.	18	14	13	4	----	0.0	0.0
Phoenix	1,108	10	107	28.66	29.78	.00	80.5	+5.5	107	31	96	58	20	65	40	57	37	26	T.	−0.1	0	3,886	w.	20	s.	25	29	2	0	1.0	0.0	0.0
Yuma	141	9	54	29.65	29.79	.00	80.8	+4.6	109	31	98	55	20	64	45	60	44	37	0.00	0.0	0	3,207	w.	22	nw.	19	30	1	0	0.2	0.0	0.0
Independence	3,957	6	27	25.92	29.90	+.06	68.7	+5.7	91	17	83	47	14	54	37	51	----	----	T.	−0.2	0	----	s.	----	----	----	19	9	3	----	0.0	0.0
Middle Plateau							59.2	+3.3										38	0.52	−0.5										3.2		
Reno	4,532	74	81	25.46	29.90	−.01	61.0	+7.4	88	30	77	34	8	45	42	46	34	44	0.72	+0.1	3	4,277	w.	33	w.	13	22	6	3	3.0	0.0	0.0
Tonopah	6,090	12	20	----	----	----	60.4	----	84	31	71	37	19	50	29	44	28	32	0.10	----	3	----	nw.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.61	29.96	+.05	58.8	+4.9	90	31	77	29	8	41	49	42	26	36	0.14	−0.7	3	4,809	ne.	28	nw.	7	22	9	0	2.1	0.0	0.0
Modena	5,473	10	43	24.60	29.89	+.07	55.7	+2.2	85	31	73	31	9	39	43	41	25	40	0.72	−0.1	5	7,358	w.	37	n.	2	16	11	4	3.7	0.0	0.0
Salt Lake City	4,360	163	203	25.61	29.94	+.08	59.8	+2.4	89	31	70	36	20	49	35	45	30	37	0.58	−1.3	4	5,376	nw.	30	nw.	7	15	13	3	3.3	0.2	0.0
Grand Junction	4,602	60	68	25.36	29.91	+.08	60.6	−0.5	87	31	74	34	11	47	38	44	28	36	0.44	−0.4	5	4,288	n.	38	nw.	7	15	10	6	3.8	0.0	0.0
Northern Plateau							60.8	+4.2										44	0.23	−1.2										4.8		
Baker	3,471	48	53	26.47	30.04	+.08	54.8	+3.1	87	30	70	28	21	40	43	44	33	50	0.26	−1.3	5	4,268	se.	25	sw.	31	13	11	7	4.7	T.	0.0
Boise	2,739	79	87	27.15	29.98	+.04	61.4	+4.3	92	31	75	32	8	48	38	47	32	40	0.01	−1.4	1	4,258	nw.	24	nw.	31	10	13	8	5.0	0.0	0.0
Lewiston	757	40	48	29.20	30.00	+.04	63.9	+4.4	97	13	78	38	21	50	46	----	----	----	0.36	−1.2	4	2,980	e.	35	nw.	6	9	14	8	5.4	0.0	0.0
Pocatello	4,477	60	68	25.47	29.95	+.06	56.6	+2.8	86	31	70	28	8	44	38	43	30	44	0.36	−1.2	5	5,056	se.	37	sw.	7	12	15	4	4.4	T.	0.0
Spokane	1,929	101	110	27.95	29.98	+.02	60.0	+4.5	93	13	73	36	20	47	41	47	36	48	0.26	−1.2	8	3,941	sw.	23	sw.	6	10	15	6	5.4	0.0	0.0
Walla Walla	991	57	65	28.92	29.98	+.02	64.7	+5.1	95	30	77	42	7	52	38	51	38	42	0.37	−1.2	4	3,051	sw.	24	w.	17	13	14	4	4.3	0.0	0.0
Yakima	1,076	58	67	28.85	30.00	----	64.3	+5.3	95	30	78	39	17	51	42	49	34	38	T.	−0.6	0	4,740	nw.	27	nw.	6	14	13	4	4.2	0.6	0.0
North Pacific Coast Region							57.7	+4.0										68	0.95	−1.3										5.2		
North Head	211	11	56	29.88	30.11	+.08	53.7	+2.8	85	10	58	45	15	49	28	49	47	82	1.32	−1.6	9	10,661	n.	39	nw.	6	8	16	7	5.2	0.0	0.0
Port Angeles	29	8	53	----	30.10	----	53.3	----	79	30	62	40	9	45	30	----	----	----	0.62	−0.6	7	5,252	sw.	28	nw.	6	10	14	7	----	0.0	0.0
Seattle	125	215	250	29.93	30.06	+.05	58.5	+4.0	85	10	68	41	7	50	32	50	42	60	1.02	−0.8	8	5,070	ne.	34	sw.	16	12	12	7	5.0	0.0	0.0
Tacoma	194	172	201	29.86	30.06	+.04	58.0	+3.9	84	10	68	42	20	49	38	----	----	----	1.04	−1.1	6	5,655	n.	38	sw.	6	7	19	5	5.3	0.0	0.0
Tatoosh Island	86	9	53	29.99	30.09	+.08	52.2	+2.6	65	10	56	45	16	48	14	49	47	86	1.46	−2.5	9	7,388	w.	43	e.	21	5	8	18	7.1	0.0	0.0
Medford	1,329	29	58	28.58	29.98	----	63.6	----	98	29	81	35	18	46	49	52	42	56	0.23	−1.0	4	----	nw.	28	nw.	7	13	11	7	4.6	0.0	0.0
Portland, Oreg.	153	68	106	29.89	30.05	+.02	62.7	+5.8	93	30	74	40	8	52	34	53	45	59	1.09	−1.1	8	3,807	nw.	18	w.	16	9	10	12	5.7	0.0	0.0
Roseburg	510	75	99	29.50	30.04	+.01	61.2	+5.2	94	10	75	37	18	47	48	52	44	62	0.56	−1.4	5	2,833	n.	19	sw.	13	16	11	4	3.7	0.0	0.0
Middle Pacific Coast Region							65.2	+5.4										63	0.87	−0.1										3.8		
Eureka	62	73	89	29.99	30.06	+.01	54.5	+2.5	67	24	59	44	8	50	21	51	49	84	0.49	−1.3	6	4,861	n.	32	n.	18	11	5	15	6.0	0.0	0.0
Red Bluff	330	5	58	29.55	29.90	−.05	74.4	+8.1	101	29	88	54	22	60	38	58	43	40	1.00	−0.1	3	4,928	nw.	24	nw.	18	21	4	6	3.1	0.0	0.0
Sacramento	69	106	117	29.82	29.89	−.05	69.6	+6.3	98	29	84	50	6	55	39	57	48	56	0.67	−0.1	3	6,384	s.	31	nw.	18	25	4	2	1.6	0.0	0.0
San Francisco	155	208	243	29.78	29.94	−.05	61.8	+5.0	90	19	70	50	5	54	34	54	50	72	1.10	+0.3	2	5,376	sw.	29	n.	19	11	14	6	4.8	0.0	0.0
San Jose	141	12	110	29.79	29.94	----	65.9	+5.2	95	9	78	45	7	54	41	----	----	----	1.08	+0.6	1	4,552	nw.	28	sw.	23	16	12	3	3.5	0.0	0.0
South Pacific Coast Region							69.1	+5.7										67	0.66	+0.3										4.2		
Fresno	327	89	98	29.53	29.88	−.04	73.6	+6.5	100	29	89	52	25	58	35	58	45	45	1.22	+0.8	2	5,002	nw.	27	nw.	13	20	7	4	2.8	0.0	0.0
Los Angeles	338	159	191	29.58	29.94	−.01	67.5	+5.3	87	19	75	55	22	60	27	60	56	74	0.52	+0.1	2	3,005	sw.	12	w.	28	10	17	4	4.5	0.0	0.0
San Diego	87	62	70	29.84	29.93	−.02	66.2	+5.4	77	24	71	58	22	61	17	61	59	82	0.24	−0.1	3	4,130	w.	16	w.	30	9	16	6	5.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.84	29.92	----	81.4	+2.8	92	15	87	73	2	76	16	----	----	----	7.46	+2.2	18	6,296	e.	28	e.	2	4	19	8	6.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Cristobal	36	6	97	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Alaska																																
Fairbanks	455	11	44	----	[1] 29.88	----	40.8	----	67	19	50	17	3	32	31	----	----	60	0.68	----	13	4,334	ne.	21	e.	1	5	10	16	----	2.0	0.0
Juneau	80	11	50	[1] 29.88	[1] 29.97	----	46.0	----	68	21	51	37	13	41	28	43	39	78	8.55	----	25	4,612	s.	26	se.	11	1	4	26	8.9	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1] 30.00	[1] 30.03	----	74.8	0.0	82	28	80	67	18	70	12	68	65	73	3.12	+1.4	6	5,695	ne.	25	e.	4	12	15	4	4.3	0.0	0.0

[1] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, May, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				40.5		46.1	34.9	68	28	5.40		0.0
Sydney, C. B. I.	48	29.92	29.97	0.00	50.4	+5.2	60.6	40.3	83	30	3.62	−0.15	0.0
Halifax, N. S.	88	29.86	29.97	−.01	52.0	+3.6	61.6	42.4	82	32	3.54	−0.72	0.0
Yarmouth, N. S.	65	29.84	29.91	−.07	49.8	+2.2	57.0	42.6	71	35	4.63	+1.06	0.0
Charlottetown, P. E. I.	38	29.84	29.88	−.08	50.0	+3.1	58.0	42.0	76	33	1.12	−1.79	0.0
Chatham, N. B.	28	29.81	29.84	−.11	49.3	+0.8	60.9	37.7	79	26	2.05	−1.16	0.0
Father Point, Que.	20												
Quebec, Que.	296	29.58	29.90	−.04	53.1	+3.2	63.1	43.2	82	29	4.19	+1.11	T.
Doucet, Que.	1,236				48.7		60.0	37.5	86	20	2.72		1.0
Montreal, Que.	187	29.66	29.87	−.07	57.1	+2.4	66.5	47.8	87	33	2.74	−0.21	0.0
Ottawa, Ont.	236	29.61	29.86	−.08	56.6	+1.7	67.6	45.7	89	27	1.85	−0.74	0.0
Kingston, Ont.	285	29.58	29.89	−.07	53.6	+0.7	61.0	46.3	78	30	4.28	+1.60	0.0
Toronto, Ont.	379	29.50	29.90	−.08	55.9	+2.7	65.9	45.9	84	30	1.89	−1.15	0.0
Cochrane, Ont.	930				48.0		59.5	36.5	89	22	2.28		T.
White River, Ont.	1,244	28.56	29.88	−.07	45.7	0.0	58.6	32.8	78	18	2.25	+0.30	2.5
London, Ont.	808				55.4		67.0	43.9	87	27	2.30		0.0
Southampton, Ont.	656	29.20	29.92	−.04	52.2	+1.5	61.9	42.5	86	29	2.54	+0.10	0.0
Parry Sound, Ont.	688	29.20	29.90	−.05	53.8	+2.7	63.8	43.8	81	30	1.88	−1.05	0.0
Port Arthur, Ont.	644	29.18	29.89	−.07	47.9	+2.0	58.0	37.8	90	29	2.84	+0.69	T.
Winnipeg, Man.	760	29.10	29.93	−.03	50.0	−1.6	61.0	39.0	90	16	2.43	+0.15	12.8
Minnedosa, Man.	1,690	28.12	29.93	−.03	49.6	+1.2	64.0	35.2	91	15	0.10	−1.35	T.
Le Pas, Man.	860				45.8		56.8	34.9	83	18	1.01		0.5
Qu'Appelle, Sask.	2,115	27.66	29.90	−.04	50.8	+1.0	66.4	35.2	95	16	0.40	−1.25	0.8
Moose Jaw, Sask.	1,759				55.0		71.9	38.1	96	17	0.45		1.0
Swift Current, Sask.	2,392	27.38	29.88	−.04	55.0	+4.3	71.3	38.7	94	26	0.66	−1.10	0.0
Medicine Hat, Alb.		27.44			54.7	+0.6	68.7	40.8	90	28	0.73	−0.58	0.1
Calgary, Alb.	3,428	26.26	29.80	−.08	49.8	+0.8	62.5	37.2	82	24	0.56	−1.21	3.0
Banff, Alb.	4,521	25.35	29.90	+.02	46.8	−0.2	59.6	33.9	78	25	2.02	−0.02	9.0
Prince Albert, Sask.	1,450	28.37	29.94	−.01	50.5	+2.9	64.8	36.2	89	13	0.63	−0.63	1.7
Battleford, Sask.	1,592	28.17	29.90	−.02	52.5	+1.5	67.9	37.2	89	25	0.12	−1.50	T.
Edmonton, Alb.	2,150	27.59	29.86	−.02	51.9	+1.1	64.8	39.0	81	28	1.80	+0.25	1.7
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.81	30.07	+.07	55.4	+2.9	62.9	48.0	78	43	1.48	.00	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.93	30.09	+.03	71.7	+2.3	77.2	66.2	80	61	5.09	+0.43	0.0

Late Reports, April, 1931

Stations	Altitude	Station reduced	Sea level reduced	Departure from normal	Mean	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Kingston, Ont.	285	29.67	29.99	−.03	44.4	+4.4	52.1	36.7	72	26	2.77	+0.98	3.0
White River, Ont.	1,244	28.65	29.99	−.05	32.6	−0.4	45.6	19.7	67	−2	2.81	+0.56	13.6
London, Ont.	808				44.7		55.7	33.7	78	25	3.54		4.6
Medicine Hat, Alb.		27.47			45.1	+0.6	59.4	30.8	78	13	0.15	−0.59	0.2
Calgary, Alb.	3,428	26.40	30.00	+.10	40.2	+0.6	53.9	26.5	78	13	1.11	+0.47	11.1
Banff, Alb.	4,521	25.36	29.96	+.06	38.2	+2.9	48.9	27.4	72	15	1.78	+0.70	16.1
Edmonton, Alb.	2,150	27.62	29.91	+.02	43.9	+4.0	56.8	31.0	80	13	0.45	−0.43	4.2
Kamloops, B. C.	1,262	28.72	30.02	+.09	51.5	+2.6	62.8	40.3	82	29	0.17	−0.22	T.
Estevan Point, B. C.	20				46.8		54.0	39.6	68	30	8.51		0.0
Prince Rupert, B. C.	170				45.6		52.7	38.5	70	32	10.73		0.0
Hamilton, Ber.	151	30.01	30.17	+.12	66.3	+2.4	71.7	60.9	77	58	0.73	−3.45	0.0

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GROUND PLAN OF A DYNAMIC METEOROLOGY

By Hurd C. Willett

[Woods Hole Oceanographic Institution, Woods Hole, Mass., July 10, 1931]

This is a summary of a discussion recently presented at a meeting of the New England branch of the American Meteorological Society held at the Massachusetts Institute of Technology in Cambridge.

The discussion was based on T. Bergeron's recent paper "Richtlinien einer dynamischen Klimatologie," appearing in Meteorologische Zeitschrift for July, 1930. This discussion is not limited strictly to the contents of Bergeron's paper, therefore statements made here are to be attributed directly to Bergeron only when that is specifically stated.

Bergeron's excellent effort toward a rationalization of the fundamental facts of climatology is particularly significant in two respects: (1) He has suggested a new and promising method of approach to the whole problem of the representation and explanation of climate, and (2) he offers for the first time practical suggestions as to how to introduce into statistical climatology some of the concepts, in modified form, which in recent years have been developed in connection with the analysis of synoptic weather maps.

Bergeron's main thesis may be stated somewhat as follows: Hitherto climatology has been essentially the systematic compiling of statistics on the individual meteorological elements, without much organized attempt to get at the underlying dynamic or thermodynamic phenomena in their entirety. We have complete charts of the distribution of atmospheric pressure, rainfall, temperature, wind, cloudiness, etc., but usually very little idea of just how the distributions of these elements tie up with one another, or just what sort of atmospheric activity, in toto, is behind these observed distributions. Bergeron points out, however, that this is by no means always the case. For example, in the more regular circulations of the subtropics, such as the trade wind systems, it is possible even from our present types of climatological charts to draw conclusions as to the thermodynamic basis of the observed atmospheric activity. Especially clearly marked are the more effective orographical influences in such regions. The more regular monsoon systems furnish another instance of a type of circulation which so definitely controls the climate of certain regions that it may be described completely in terms of a single atmospheric phenomenon. The best illustration of this is the Indian monsoon, where the underlying thermodynamic process is so well understood that it is necessary only to characterize a given period as one of weak or strong monsoonal activity in order to convey a comprehensive picture of the climate or climatic changes during the time in question. Here again orographical effects are readily recognized. But in general over the greater part of the temperate and northerly latitudes climatology offers no unifying picture of the prime thermodynamic forces controlling the climate. This is what a dynamic climatology should do. Therefore Bergeron undertakes to show how the concepts of air masses and fronts may be modified to furnish a key to the development of a comprehensive dynamic climatology.

If we look at almost any synoptic chart which covers a considerable area on the earth's surface, one of the things that stands out most strikingly is the existence of large scale air currents or large bodies of air at rest in which the meteorological elements are distinctly uniform in their horizontal distribution. Such extensive bodies of air which approximate a state of horizontal homogeneity in their properties we refer to as air masses. Their occurrence is due essentially to two facts. These are (1) the existence of extensive sources, or regions on the earth's surface where conditions are so uniform that the overlying atmosphere acquires horizontal homogeneity in its properties. Examples of such sources are the Arctic ice fields, snow-covered northerly continents in winter, the warm subtropical oceans, and continents, especially southerly or semiarid regions in summer; (2) the occurrence in the general circulation between subtropical and subpolar regions of large scale atmospheric movements. This makes possible large displacements of air masses from their sources with a considerable degree of conservation of certain of their characteristic properties, rather than the rapid turbulent mixing and loss of air mass characteristics which would occur if the latitudinal transport of air took place in small, disordered currents instead of in the large branches observed in such circulations.

Evidently if the existence of air masses of more or less definite characteristic properties be accepted, then their classification according to their characteristic properties and their detection on the synoptic chart become a material aid to weather forecasting. Bergeron has indicated further a classification of air masses which may be made a material aid to the understanding of climate. According to him there are two distinct methods of procedure in classifying air masses, each with its particular advantages.

(1) *The integral method.*—This method consists in picking out the most conservative or nonvariable properties of an air mass, such as the potential temperature or specific humidity, and using the characteristic seasonal values of these quantities for the classification and identification of the air masses appearing on the synoptic chart for a given region. Since the characteristic values of these conservative properties of air masses depend upon both the properties of the mass at its source and the sum total (integral) of the modifying influences to which the mass has been subjected in following its path from the source, it is evident that this method of classi-

fication can be used to advantage only at stations where a series of carefully analyzed synoptic charts based on observational material from a considerable area are prepared, for the complete life history of the air mass must be known. This follows from the fact that it is possible for two quite different air masses which have followed widely separated trajectories to arrive at the same point with approximate similarity of their conservative properties at the ground, yet with very significant differences in their vertical structure. At a forecast center where observational material from a wide network of stations is at hand, this system of air-mass classification is most advantageous, because the characteristic air masses for any given locality depend definitely upon the usual air mass sources and trajectories in that region. When the forecaster becomes familiar with these, he knows in detail the characteristics and therefore the type of weather to be expected locally with each particular air mass. On the other hand, because air masses classified in this way are essentially particular rather than general in nature, i. e., are dependent on local or regional geography, they are useless to the climatologist, who must have a perfectly general classification applicable anywhere on the earth's surface.

(2) *The differential method.*—This method consists in picking out the most variable or non-conservative properties of the air mass, in particular the lapse rate at lower levels and making the changes (differences) in the air mass properties effected by its most recent history, as indicated by the lapse rate, the basis for the air mass classification. On this principle all air masses may be grouped in the following four perfectly general classes:

(*a*) Warm: Air masses warmer than the surfaces over which they are moving, hence with a tendency toward increasing stability and stratification.

(*b*) Cold: Air masses colder than the surfaces over which they are moving, hence with a tendency toward increasing lapse rate and specific humidity.

(*c*) Indifferent: Air masses at the same temperature as the surfaces above which they occur.

(*d*) Unknown: Air masses whose temperatures relative to the underlying surfaces are unknown.

Classes (*a*) and (*b*) are the really important ones for this discussion; (*c*) applies primarily to air masses at their sources, or at least only to stagnant synoptic situations; (*d*) is of little significance, for as we shall see presently the properties of warm and cold masses are so distinctive that an experienced observer can readily detect them without the aid of any instrumental observations.

Although this classification of air masses might not be of as much assistance to the weather forecaster as the first method outlined above, it has the following definite advantages, in particular for the climatologist:

(1) It is perfectly general, applying equally well in polar and equatorial regions. It must be emphasized that the warm and cold designations indicate nothing about the actual temperature of the air mass itself, but only its temperature relative to the underlying surface. In fact, it is readily seen that cold air masses will tend to predominate at low latitudes, warm air masses at high latitudes. Furthermore, the transition from a warm to a cold or a cold to a warm air mass can take place very suddenly, and is especially likely to happen in summer and winter with the movement of air from land to water or vice versa. It will be found that such a change is followed by a very rapid adjustment of the characteristic properties of each mass, as outlined below, to those required for its new classification, at least at lower levels. A variable life history of the mass will be indicated by variable characteristics at different levels, the older influences appearing at the upper levels.

(2) The detection of the warm and cold mass differences is so easy to make that an experienced observer can usually classify the prevailing type of air mass without the aid of instruments or synoptic chart. The properties to be noted and the differences characteristic of warm and cold masses, according to Bergeron may be summed up briefly as follows:

(*a*) Lapse rate: The cold mass will have a steep lapse rate (equal to or greater than the saturation adiabatic), and the warm mass a stable lapse rate, probably well-marked stratification, and often even inversions in the actual temperature lapse rate. Although the direct measurement of the lapse rate requires instrumental observations at the ground and in the free air, a reliable qualitative estimate of the steepness of the lapse rate may be made by direct observation of properties (*b*), (*c*), (*d*), and (*e*) below.

(*b*) Turbulence: Because atmospheric stability tends to damp out the eddy energy of mechanical turbulence and to prevent convective turbulence, it follows that the winds in warm air masses are much less gusty than in cold masses. This difference is so marked that it is readily detectable by any trained observer, and is quite striking in anemograph records. Bergeron has found in one clearly marked transition from a typical warm mass to a typical cold mass that although the prevailing wind velocity was reduced by one-half, the absolute magnitude of the variations in wind velocity due to gustiness remained practically unchanged.

(*c*) Horizontal visibility: Since a steep lapse rate favors convective turbulence and the upward spread of mechanical turbulence, it tends to effect a uniform distribution throughout the atmosphere of both moisture and the solid impurities, dust, and smoke. Therefore in warm air masses the obscuring dust and smoke are kept at low levels, particularly below any marked inversions. Consequently inversions result in haze and smoke layers sharply bounded at their upper edge. And in general, in warm masses visibilities are markedly poor at low levels, markedly good at upper levels, whereas in cold masses just the reverse is true.

(*d*) Cloud forms: The effect of dust on horizontal visibilities in warm and cold air masses is accentuated by the typical condensation forms. Since the same distribution of water vapor as of dry dust is typical of warm and cold air masses, it follows that in warm-air masses condensation tends to take place at low levels, resulting characteristically in either surface fog or a low thick stratus deck. In cold-air masses, on the other hand, the moisture is carried up to cooler levels by convective turbulence, the condensation occurring aloft as cumulus or cumulo-nimbus clouds, usually only a broken cloud with excellent visibilities below.

(*e*) Precipitation forms: Evidently the typical form of precipitation in the warm-air mass, if any occurs, will be of the mist or drizzle type, from a low stratus or nimbus and rather small in amount. In the cold-air mass the typical form will be the instability shower, of short duration, but frequently heavy. Hail and thunderstorms will belong to this type. All the typical warm and cold air mass characteristic condensation forms will be more in evidence and more nearly complete in the case of maritime than of continental air masses, due to the greater moisture content of the former. The differences in precipitation forms in these two air masses become particularly significant in the case of steady air movement

on a high coast line or against any marked orographical barrier. In the case of the stable warm-air mass the tendency is to a continued stratified air flow which will resist vertical displacement and seek the easiest way around rather than over the obstacle. Hence the warm air drizzle rain is comparatively little intensified by orographical influences. On the other hand, in the unstable or conditionally unstable cold mass such an obstacle furnishes just the needed initial impulse to start extensive overturning of the atmosphere. Therefore, on the windward side of orographical barriers the cold-air mass may be expected to deposit copious precipitation in an almost unbroken sequence of heavy showers.

From the above considerations it is evident to what a large extent the commonly observed meteorological elements, visibility, gustiness, cloud forms, and type and amount of precipitation depend upon the prevalence of the warm or cold air mass type. And since climate is only the integral over a period of time of the daily weather, it is obvious that the predominance of one or the other of these air mass types will be a controlling factor in the climate, and will in itself serve to a considerable degree to classify and explain the climate. Therefore Bergeron concludes that the first thing to be done to develop a dynamic climatology is to record regularly by direct observation the prevailing air mass type at all stations whose records are to be used for climatological purposes, just as is done with any meteorological element. A trained observer could do this with little difficulty.

But this is only half the picture. It remains to take into account the irregular variations that go with migratory cyclones and anticyclones, and these tie up with the problem of the genesis and displacement of fronts. Quite as important as the characteristic weather phenomena belonging to each of the air mass types, are the phenomena which occur at the boundaries or fronts between air masses. Charts showing the mean pressure distribution over the northern or southern hemisphere for a given month, or maps of the prevailing winds such as those of Köppen, indicate clearly the tendency to the existence of more or less permanent regions of seasonal high and low pressure which dominate the mean air movement over the greater portion of the earth's surface. Such semipermanent areas of high and low pressure are sometimes referred to as "centers of action", for they are the fundamental thermodynamic units controlling the general circulation. Their essential cause is found in the thermal differences existing in the troposphere over large areas following the establishment of convective or radiation equilibrium in response to differences in the earth's surface. Examples of well-marked centers of action are the Aleutian and Icelandic lows and the north continental highs in winter, and the Azores and Pacific highs which are best developed in summer. It is the existence of these centers of action that is responsible for the large branches in the general circulation which enable us to speak of extensive air masses with characteristic properties. A chart of prevailing winds will show furthermore that there are certain regions where air currents or air masses of widely different origin and properties tend to be brought into more or less direct opposition. Such opposing trends in the movement of air masses of northerly and southerly origin evidently tend to greatly intensify, locally, the normal poleward temperature gradient, that is, they constitute a region of marked front formation, or what Bergeron calls frontogenesis. Correspondingly there are also regions of marked divergence or dissipation of the horizontal temperature differences, a process which Bergeron calls frontolysis. These two processes are particularly important because they largely determine the activity of the migratory cyclones and anticyclones. It must be emphasized, however, that on any particular occasion the actual position of the front between two characteristic branches of the general circulation may be very far removed from the mean position as indicated by the line of convergence of the wind systems on the mean wind charts. On the other hand, if we designate the mean position of such a region of frontogenesis as a climatic front, then we can say that such a climatic front will be a region of maximum frequency of migratory cyclones. Such a region which will be characterized in its climate by a maximum frequency of warm, cold, and occluded front passages with their attendant cloud systems and typical rain belts, and a maximum frequency of change of the prevailing air mass type. Bergeron has represented, on the basis of Köppen's mean wind charts for the northern hemisphere in January and July, respectively, the winter and summer positions of the principal climatic fronts on the northern hemisphere, and shows in general how the resultant scheme fits the observed facts. He distinguishes between the arctic, the polar, and the tropical fronts. The arctic fronts are the most northerly, the air masses to the north coming directly from the arctic. On the polar fronts of middle latitudes we find the contrast to be essentially that between the subpolar and the subtropical air masses. On both of these fronts there are large temperature differences. Therefore the arctic and polar fronts are characteristically regions favorable to the genesis and maintenance of extra tropical migratory cyclones, with all the weather sequences which that implies. The tropical fronts, on the other hand, are distinctly different. They represent essentially convergence of subtropical and tropical air masses, whose temperature differences are characteristically small. They are primarily regions of light variable winds between the prevailing wind systems of the subtropics and tropics, such as the doldrums. Hence they are characterized by oppressive heat and over the oceans by high humidity, heavy instability showers, and under favorable conditions even by tropical hurricanes, but not by clearly marked front passages or typical warm and cold front rain belts.

Obviously the climate at any place depends on the prevailing air mass type, and the frequency of front passages, i. e., nearness of the climatic fronts. Both of these in turn depend upon the position, extent, and activity of the different centers of action. Therefore the fundamental problem of a dynamic climatology which aims to present the underlying dynamic and thermodynamic phenomena of the atmosphere in their entirety is to account completely for the mean activity of the centers of action. The first step toward the solution of this problem is the development of some satisfactory method of representing the state of activity of the centers of action, in order that normal and abnormal conditions may be clearly represented and recognized. For this purpose Bergeron used Köppen's mean wind charts as the best means at hand for a preliminary study.

An understanding of the dynamic and thermodynamic factors controlling the centers of action will explain not only the mean activity of these atmospheric phenomena (climate), but also variations in and departures from this mean activity. The shortest and most irregular of these changes we refer to as changes in the weather. For instance, Bergeron shows, in accordance with Köppen's mean wind chart for January, that for this month in the eastern United States the climatological front (polar) between the cold continental air masses of the North

American winter anticyclone and the warm maritime air masses belonging to the circulation of the Bermuda high (westward extension of the Azores high) extends from southern Florida northeastward to the vicinity of Bermuda and on into the north Atlantic. Thus Köppen indicates prevailing northwest winds on the north Atlantic and northeast on the south Atlantic coast. On the other hand, we know that this front, even in winter, may be displaced northward as far as to the Canadian border, and again far southward until lost in the trade winds as the successive warm and cold outbreaks belonging to the two circulations advance and recede. Always the cyclones tend to develop and move along the front as it is displaced. Such changes as these constitute weather, and have no place properly in a discussion of climate. Yet in the aggregate they determine climate, and as we shall see presently, no hard and fast line can be drawn between weather and climate, either in definition or in the controlling factors.

Besides the irregular variations of a few days or weeks which constitute what we call the weather, there have long been observed, statistically, anomalies of the various meteorological elements of months and even years, some of which recur with a certain degree of regularity. Such anomalies will usually be found associated with some abnormality in activity or position of one of the centers of action. Whether variations such as these will be classed as climatic changes or not depends entirely on the arbitrary choice of the period of time which shall be considered sufficient to determine a climate. Yet we know that even if centuries are used in establishing climatic means, still changes of climate take place. There occur meteorological anomalies of every length from a few days to thousands of years, and of every degree of irregularity, yet they are all apparently associated with the same sort of abnormalites in the centers of action, whatever the underlying causes. Hence it becomes evident that in climatology, as well as in the study of the daily weather, it is necessary to consider not only mean or normal conditions, but also the disturbing factors.

A good instance of an anomaly lasting a few months is that of the drought which reached its peak in the eastern United States during the summer and autumn of 1930. During that time the Bermuda high was unusually well developed to the westward, therefore, persistently predominant in the circulation of the southeastern United States, so that the polar front, or cyclone path, was displaced northward from its normal position. As a consequence the normal cyclonic or frontal rain was largely missing in the eastern United States, and this in turn lessened the evaporation from the earth's surface which probably is the source of the greater part of the moisture of summer showers and thunderstorms. There are many well known more or less irregularly periodic displacements of this sort of considerably longer duration. Probably the best known and most studied of these longer period displacements of the climatic fronts are those connected with the 11-year sun spot cycles. As to the reality of many of these changes there is not the slightest doubt, but in the dynamic or thermodynamic explanation of them not even a beginning has been made. Some of the factors, which have been suggested as of importance in the control of climate and climatic changes (see Humphrey's Physics of the Air, Pt. V), may be listed as follows:

(1) *Radiation.*—(*a*) Solar: Variations in the solar constant, such as those belonging to the 11-year sunspot cycle and possibly others of longer or shorter duration.

(*b*) Atmospheric: Changes in the atmospheric composition (especially the amounts of water vapor, ozone, or carbon dioxide) or of its content of impurities which reflect or scatter solar radiation (especially volcanic dust).

(2) *Changes in the earth's surface.*—(*a*) Glaciation: This favors both by radiation and reflection further cooling of the overlying atmosphere and the strengthening of local anticyclonic circulation.

(*b*) Desiccation: Increasing aridness over a portion of the earth renders that region one of greater extremes in climate.

(*c*) Distribution of land and water: Changes in the position or ratio of land and water areas must affect the nature of the general circulation profoundly, for they seem principally to determine the centers of action. Furthermore, orographical changes may greatly affect the atmospheric circulation and climate, while the influence of similar changes in submarine orography on the oceanic currents may have an equally far-reaching effect on climate.

(*d*) Ocean surface temperatures: Anomalies in ocean surface temperatures and currents much like those in the atmosphere are generally recognized phenomena. These may in part be caused by atmospheric irregularities, but certainly there are also independent factors involved. These must be taken into account especially in explaining the short period atmospheric anomalies. It is very difficult to distinguish between cause and effect in atmospheric-oceanic interactions.

(3) *Persistent tendencies in the circulation of the substratosphere.*—It has been shown analytically and statistically that for short period surface pressure variations the warm and cold air currents of the substratosphere (actually warm and cold here, not relative to the surface) play an important rôle. Even important irregular change in the greater centers of action are frequently explained in this way. Clearly then, whatever the dynamic and thermodynamic controls of the circulation at the base of the stratosphere, persistent or variable tendencies in the circulation here will have corresponding secondary effects at the earth's surface.

It is scarcely necessary to point out how fundamental for the problem of long range weather forecasting is the development of a comprehensive dynamic meteorology in the sense outlined in this paper. In fact, the two problems are identical, for such a dynamic climatology is nothing other than the physical basis of long-range forecasting. At present there are numerous schools of thought which have been developed in connection with this problem, each based on only one or two of the above-mentioned factors of climatic control, and usually mutually exclusive and even antagonistic. Furthermore they are entirely empirical, based on experience or correlations and utterly lacking in any attempt at dynamic explanations. A dynamic climatology that can finally explain the intensity and displacements of the centers of action and of the climatic fronts will make possible the forecasting over considerable periods not only of the cyclonic activity and frontal rain, but also of the prevailing air mass types with all the attendant weather phenomena.

To sum up, we might say that if a dynamic climatology is to aim at a presentation of the several complete thermodynamic units controlling the climate of a region rather than the unrelated distribution of the individual meteorological elements, it should be developed somewhat as follows:

(1) Some method of representing the position, horizontal extent, and degree of activity of the different centers of action should be chosen, so that mean values and long-period departures from the means may be found and

studied. For this purpose Bergeron has made use of Köppen's mean wind charts as the best available criterion.

(2) Mean positions and long-period departures from the mean positions of the climatic fronts must be noted. Explanation of departures from the normal position of such zones, i. e., displacement of the belts of maximum storminess, or cyclone paths, must be looked for in the dynamic or thermodynamic factors (see list above) controlling the particular center of action whose displacement or changed activity is responsible for the displacement of the climatic front.

(3) Finally there is required the systematic observation of the frequency of occurrence of warm and cold air masses at each station, and the relation of all the meteorological elements, especially the hydrometeors, to the prevailing air mass type. The frequency of change from one air mass to another should give in temperature regions a measure of the proximity and activity of the climatic front, and an indication of the contribution of active front passages to the climate of the region, particularly the precipitation and cloudiness.

WINDSTORM IN THE LOS ANGELES AREA NOVEMBER 22, 1930, AND SOME EFFECTS OF WIND FLOW IN A MOUNTAINOUS REGION

By GEORGE M. FRENCH

[Weather Bureau Office, Los Angeles, Calif., July, 1931]

Near midnight of November 21, 1930, one of the strongest winds of record began in the Los Angeles area and continued until about midnight of November 22. Winds aloft and on the surface were from the northeast except where they were deflected by topography.

Following the passage of a low over the southern portion of the western plateau region on November 18, 1930, a high pressure area moved in rapidly from the Pacific Ocean over the Northwestern States and when reaching the plateau region became almost stationary as is common in that region especially during the early winter months. This high built up rapidly being reinforced by additional ocean highs and as shown on the 8 p. m. synoptic chart of November 21, it was central over Idaho, eastern Oregon, and western Montana with a pressure of 30.82 inches. The pressure gradient had by this time become quite steep between the plateau and the coastal valleys of California and the high was still increasing in energy.

The influence of this high was little felt in southern California as far as either surface winds or those aloft were concerned during the day of November 21, 1930, but a little before midnight on that date surface winds increased rapidly and became strong with frequent gusts of gale force. The next morning, November 22, the synoptic chart showed the high central in Idaho and northwestern Wyoming with the highest reading at Yellowstone, 31.02 inches, reduced to sea level.

Three hourly airway weather maps of California for 11 a. m., 2 p. m., and 5 p. m., eastern standard time, are shown by figures 1, 2, and 3. As the map is on quite a large scale, isobars are drawn for every 0.05 inch difference in pressure. These maps show the steep gradient that prevailed over the mountains on November 22 and the relatively low pressure on the lee side of the mountains, which is largely due to the strength of the wind.

From experience the writer believes that under ordinary pressure gradients, mountains as high and as precipitous as the San Gabriel Range act as a barrier to north winds in the Los Angeles area. In such cases high winds proceed southward over the mountains and remain aloft, gradually lowering and reaching the surface in the vicinity of the ocean shore line or farther out, leaving the Los Angeles area in light to moderate variable winds. However, in such cases the wind pours through the low points in the mountains, as for example Cajon Pass, and frequently proceeds southward at gale force through Santa Ana Canyon in the Santa Ana Mountains and thence southward to the ocean, thus producing the "Santa Ana" as the wind of this type has been popularly called in southern California. I once had the opportunity to observe such a wind from the top of Santiago Peak. The course of this rapidly moving air was easily traceable by the dust and could be followed in that manner from Cajon Pass to the ocean.

It appears, by study of winds in the Los Angeles area, that if the gradient is quite steep between the plateau high and the coastal area that high northerly winds in passing over the mountains will not only reach the surface in lee of low passes but will also follow the contour of the lee side of the high mountains and in that case high northerly winds are general over the whole Los Angeles area as was the case on November 22, 1930.

There were three points in and near Los Angeles where wind instruments were located at the time of the storm. They were located as follows: Weather Bureau office, Los Angeles; airport at Alhambra, and the Weather Bureau airport station, Glendale. The writer was located at the latter point. The strength and duration of the wind was quite similar at Glendale and Alhambra but the velocities were lighter and the duration much shorter at the Weather Bureau office, Los Angeles, a condition that frequently prevails in times of high northerly winds. The Weather Bureau office in Los Angeles is remarkably free from high northerly winds although the exposure is excellent.

The high winds at Glendale had two maximum periods on the surface, 2 to 4 a. m. and 12:30 to 4 p. m., with gusts in excess of 60 miles per hour during the latter period. As far as could be ascertained, the highest winds aloft occurred near the middle of the forenoon.

The first upper air observation on the day of the wind storm was attempted at 3 a. m. but with several attempts only 3 minutes were secured due to dust. Shortly before 9 a. m. upper air observations were again attempted and after several trials one was secured of nine minutes with an indicated altitude of 5,600 feet. In each of the attempts the balloon moved southwestward rapidly in the beginning then was retarded at approximately the same length of time after release and then would again move out much more rapidly than before. The first attempts were lost soon after reaching the second high velocity either due to dust or to the vibration of the theodolite.

In Figure 4 a cross section of the mountains and valley north and south and passing through the airport station at Glendale is represented. Wind flow over the mountains and valleys is represented by arrows flying with the wind giving my idea of both the nature of the flow over the mountains and the relative speed. The relative speed is indicated by the length of the arrows, longer arrows representing greater speed. This is based on available data and the general knowledge that I have gained mostly in the aerological work of wind flow over a mountain range.

During the wind storm occasionally the wind would suddenly shift at the Glendale station to south or southwest and blow nearly as hard from that direction as it had from the northeast, reaching extremes of 50 miles per hour or more. This is believed to be the result of vertical eddies as represented in Figure 5. This reversing of the wind also occurred at Alhambra but was little noticed at the Weather Bureau office in Los Angeles, which point is farther removed from the mountains.

Flying was discouraged as far as possible in all our contacts with pilots both as to conditions aloft and especially on account of bad wind conditions for landing or taking-off.

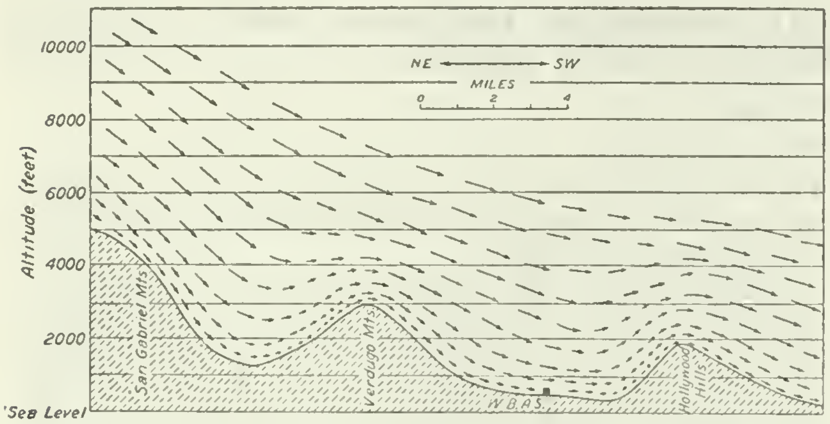

FIGURE 4.—Cross section showing the contour of the land from a point near the top of Sister Elsie Peak, in the San Gabriel Mountains, southwestward through the Verdugo Mountains and Weather Bureau Airport station in the San Fernando Valley, thence through the Hollywood hills near Cahuenga Peak. Arrows indicate the wind flow believed to have prevailed during the greater portion of the wind storm of November 22, 1930

Nearly all the scheduled flights were canceled, but four known flights were made. One scheduled flight was accomplished from Salt Lake City to Los Angeles which was made in 4 hours and 15 minutes as compared with 7 hours and 15 minutes scheduled time. Another flight was attempted from Los Angeles to San Francisco. The pilot came into our office after the attempt and said that he went up to 8,000 feet to avoid extreme bumpiness and was making an air speed of 110 miles per hour. He noticed that he was making very little if any headway and he sighted on a water tank below him and found that he was not only making no headway forward but was being carried slowly to one side. He immediately landed at Glendale and found landing conditions very dangerous.

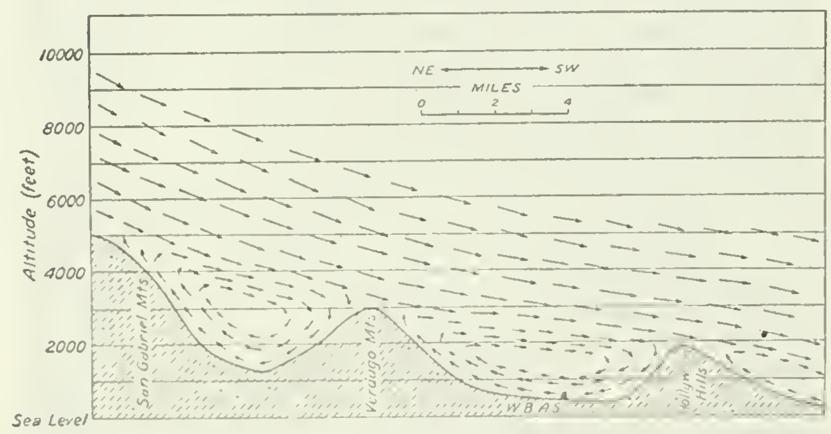

FIGURE 5.—Cross section showing the contour of the land from a point near the top of Sister Elsie Peak, in the San Gabriel Mountains, southwestward through the Verdugo Mountains and Weather Bureau Airport station in the San Fernando Valley, thence through the Hollywood hills near Cahuenga Peak. Arrows indicate wind flow believed to have taken place over this contour on November 22, 1930, showing vertical currents in the lee of the higher hills

Our upper air observation at 9 a. m. was taken shortly after the attempted flight described above. The following velocities were indicated from the data obtained from the pilot balloon flight (altitudes in feet and wind speeds in miles per hour):

Surface, NNE. 19.	3,200 feet, NNE. 21.
700 feet, NE. 34.	3,800 feet, NNE. 36.
1,400 feet, NE. 51.	4,400 feet, NE. 102.
2,050 feet, NE. 57.	5,000 feet, NE. 168.
2,650 feet, NE. 47.	5,600 feet, NE. 186.

This observation is also plotted on Figure 6 for direction and velocity with elevation in meters and velocity in meters per second.

Again referring to Figure 4 it was found that by comparing distance out of the balloon with the distance of the Hollywood hills from the airport station that the balloon would have reached the area of rising currents and diminished velocity on the windward side at about the time the run showed a sharp decline in velocity. I believe it is therefore safe to assume that the apparent decrease in velocity was partly due to retarded wind movement and partly to rising currents which would indicate a lighter velocity according to our method of determining winds aloft.

The diminished wind velocity on the upper air observation was immediately followed by a rapid increase in velocity which also conforms with Figure 4, as it is believed that the balloon was then entering the increased wind velocity indicated on the lee side of the Hollywood hills and in addition there was a downward movement to the air giving a lower elevation angle than should have been recorded which in turn indicates a velocity greater than what actually existed. Winds undoubtedly occurred, however, of 110 miles per hour or more as evidenced by one aviator's experience.

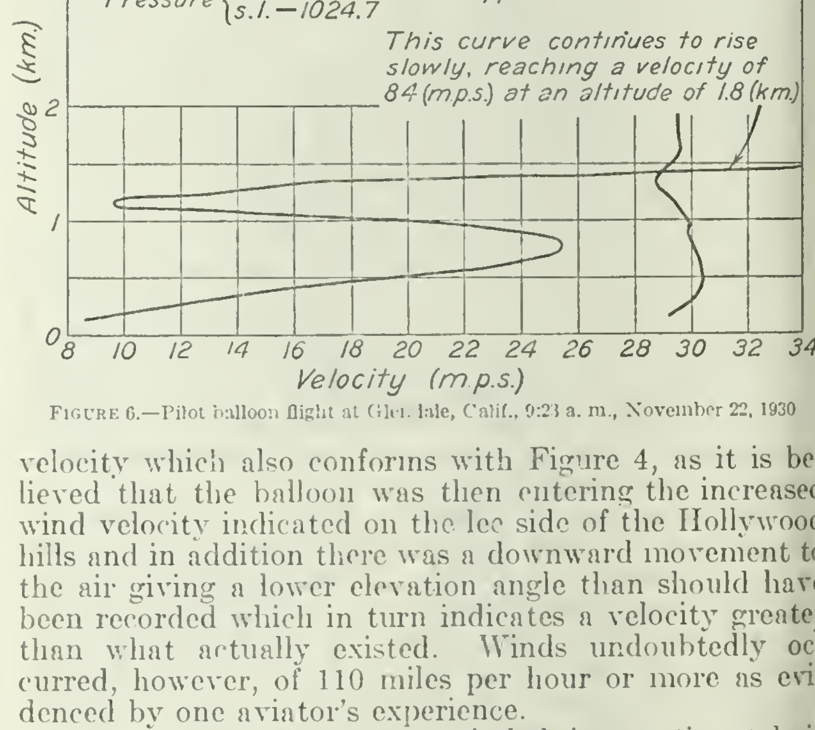

FIGURE 6.—Pilot balloon flight at Glendale, Calif., 9:23 a. m., November 22, 1930

In most cases where strong winds bring continental air into this region, with the exception of cases where precipitation has occurred just previously, very dry and clear weather prevails. However, in this case there was sufficient moisture in the continental air that the forced convection over the mountains formed storm clouds all along the north slope of the San Gabriel and San Bernardino Mountains and blizzards prevailed in that region. The clouds dissipated rapidly on the lee side and the air was relatively dry at Glendale. This storm condition subsided as soon as winds aloft had materially decreased.

Considerable damage was done during the storm. A trimotored plane was torn from its anchorage during the early morning hours at the Grand Central Airport, Glendale, and was rolled by the wind about half a mile across the field and left upside down at the opposite end. The plane was so badly damaged that it could not be

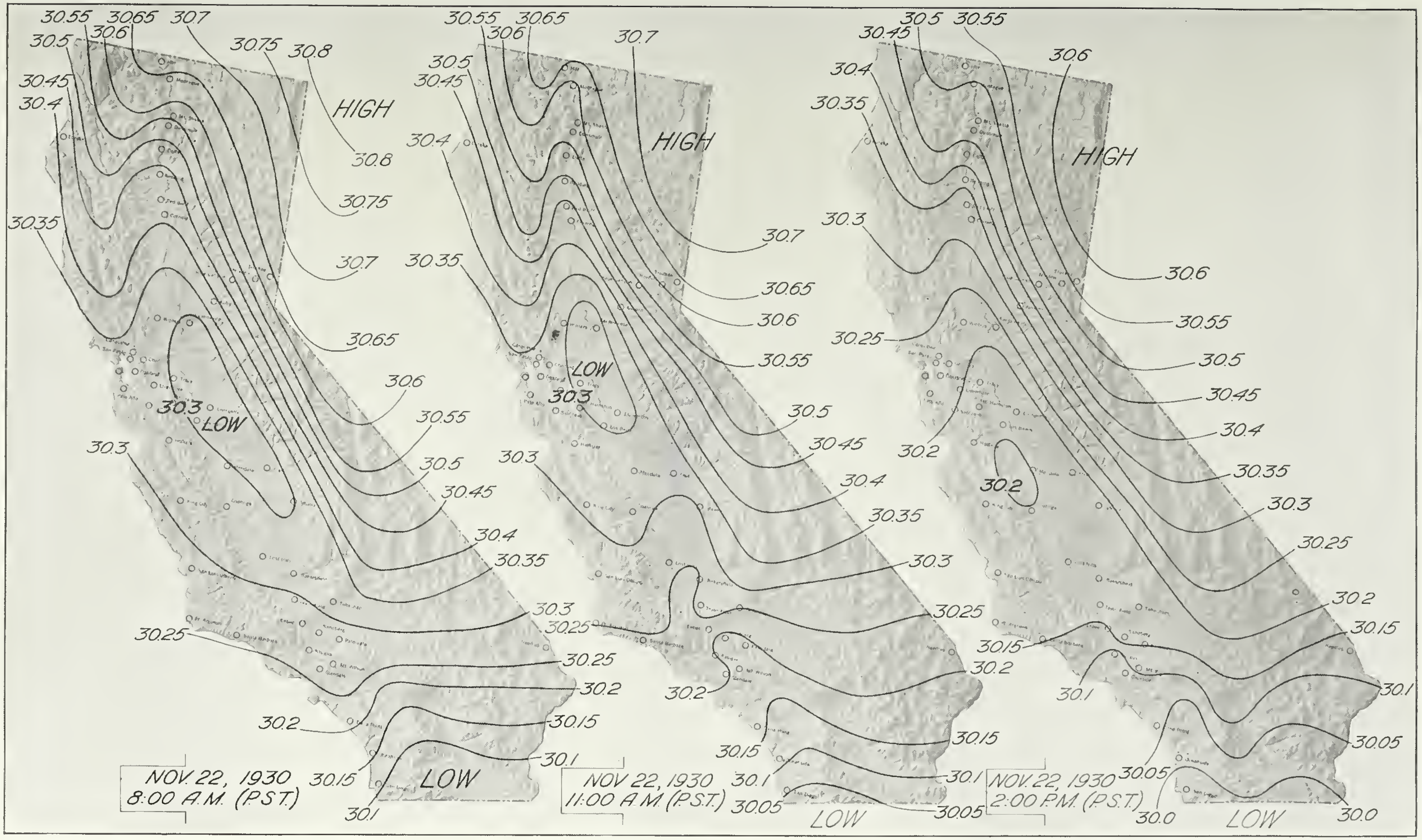

FIGURE 1.—Weather chart 8 a. m. (P. S. T.) November 22, 1930

FIGURE 2.—Weather chart 11 a. m. (P. S. T.) November 22, 1930

FIGURE 3.—Weather chart 2 p. m. (P. S. T.) November 22, 1930

repaired. Other damage, such as small buildings demolished, occurred on the field. In other parts of the city telegraph poles, trees, small buildings, and roofs were either damaged or blown down, and a few people lost their lives by being hit by falling objects.

It is my belief in studying this storm and the available data in connection with other local and general winds in this area that moderately strong winds will generally flow over a mountain having gentle sloping sides, especially if the mountains is not very high, in much the same manner as the flow of air that moves over the cambered surface of an airplane wing, the result being reduced pressure [1] and increased velocity of wind in lee of the highest point. In such cases, I believe that a high precipitous mountain will act as a barrier and the wind will not descend directly down the leeward side but reduced pressure will occur on the lee side as in the other case. When very high winds prevail, I believe that they will often descend the leeward side even of high precipitous mountains, but the flow will be variable and great turbulence prevail.

[1] Detailed airway weather maps for California at times showed peculiar pressure distributions which seemed to be out of harmony with the rest of the map. Mr. D. M. Little first drew these pecularities to my attention and pointed out that it was due to the compressing of air on the windward slopes of mountains and the expansion on the leeward side as a result of the general wind flow over the region.

THE GOTHENBURG, NEBR., TORNADOES JUNE 24, 1930

By Alfred Russell Oliver

Tuesday evening, June 24, 1930, a series of tornadoes began in Lincoln County, Nebr., swept southeastward across Dawson County, and ended in Phelps County, leaving behind them a path of destruction 70 miles long and varying in widths from a quarter of a mile to 2 miles. (Fig. 1.) The storm was first observed about 3 p. m., struck its first blow about 5:30 p. m., and was over by 8 p. m.

The weather map for Tuesday morning, Figure 2, shows that almost the entire United States west of the Mississippi was covered by an area of low pressure. Over most of this area the variations in pressure did not exceed two-tenths of an inch, the extremes being 29.7 and 29.9 inches. Thus the barometric gradient over the entire western part of the country was very slight. These conditions are typical of those which produce the common thunderstorm of this country. A high, with a pressure of 30.1 inches, was centered over western Oregon; another, with a pressure of 30 inches, existed over southern Louisiana. (See figs. 2 and 3.)

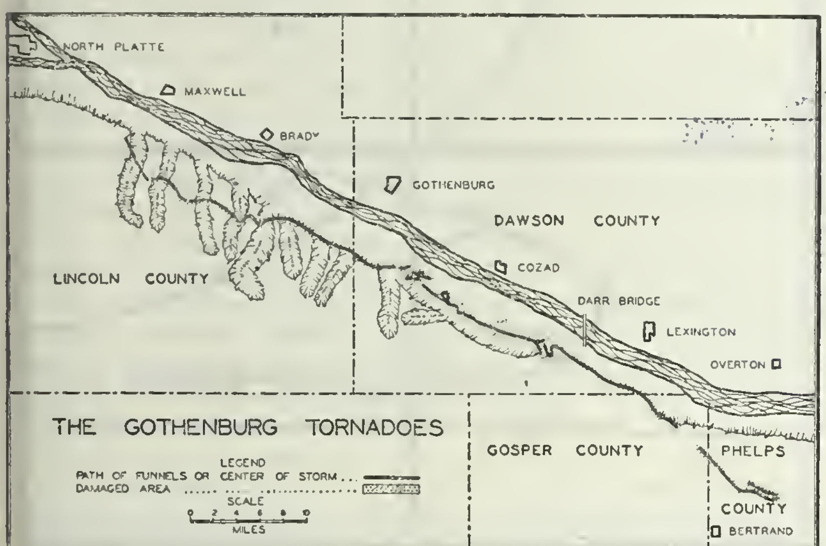

Figure 1

The tornadoes occurred between 5 p. m. and 8 p. m. In some cases coincident with them, but generally somewhat later, violent thunderstorms, accompanied by strong winds, occurred at several points in Nebraska, north, south, and east of the tornado belt, but there was no general storm over the State. That tornado conditions seem to have started developing west of North Platte is indicated by reports of violent agitation of the clouds 15 miles west of there. These clouds moved eastward along the Platte Valley. At North Platte two clouds appeared to unite, one coming from the west, the other seeming to materialize out of the air overhead. Both were rolling and tumbling and boiled upward as they came together. The new cloud continued southeastward about 14 miles toward Boxelder Canyon, becoming darker, more agitated, and continuously more threatening. Behind this cloud was the thunderstorm which brought the rain and hail, a not unusual condition under such circumstances.

The location of North Platte in the formative area of the tornado makes the weather observations there especially significant. In this connection it should be

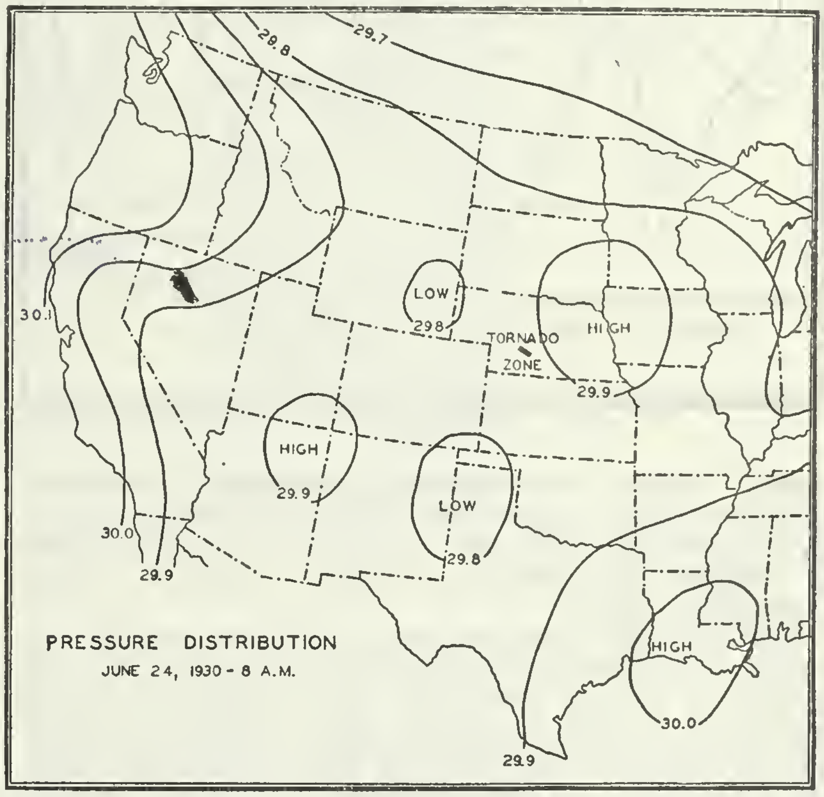

Figure 2

remembered that the storm was forming from 3 p. m. to 5:30 p. m. and was over by 8 p. m. A heavy thunderstorm prevailed at North Platte [1] from 3:55 p. m. to 5:45 p. m., with a rain lasting until 4:29 p. m., then a heavy hail for 15 minutes, and then rain again until 4:57 p. m. The rainfall for the afternoon was 0.32 inches. Hailstones 2 inches in diameter were picked up, consisting of from 75 to 100 ice pellets frozen together. A continuous roaring, as of trains passing through a tunnel, was heard before and after the rain and hail. The barometer fell steadily from 26.98 inches at noon to 26.85 inches at 7 p. m. The temperature dropped from

[1] Detailed information concerning conditions at North Platte was supplied by Mr. A. W. Schilling, junior meteorologist there.

86° at noon to 70° at 5 p. m., rose to 77° at 7 p. m., and then began the normal nightly decline. The humidity was slightly above normal at 7 a. m., and about 40 per cent above it at the noon and evening readings. The wind was moderate during the afternoon, but very changeable, as shown by the following table:

1:00 p. m.–4:36 p. m., southeast.
4:36 p. m.–4:37 p. m., south.
4:37 p. m.–4:44 p. m., east.
4:44 p. m.–4:45 p. m., north.
4:45 p. m.–4:49 p. m., northwest.
4:49 p. m.–5:00 p. m., west.
5:00 p. m.–5:04 p. m., south.
5:04 p. m.–.......... east.

The variable wind, the rapid drop in temperature, the steadily falling barometer, and the unusually high humidity indicate very unstable atmospheric conditions. Observers noticed that while only a gentle breeze existed on the ground, the clouds at higher levels were carried in different directions, tossed and tumbled by strong conflicting currents.

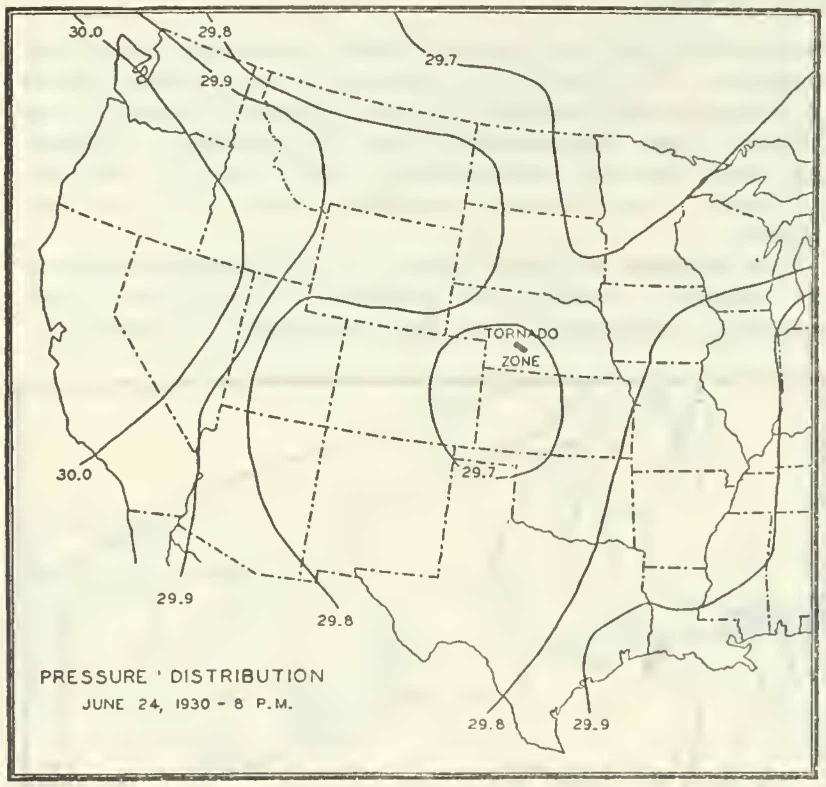

FIGURE 3

The tornado began to assume definite form in the vicinity of Boxelder Canyon, the process being described by several observers. The afternoon was hot and sultry, with no wind for an hour before the tornado. The sky to the north and west was overcast by a huge black thundercloud which extended southward beyond the bluffs about 5 miles. Below this were two other layers of clouds. The upper layer, some distance above the ground, was white and traveling due north; the lower layer, close to the ground, appeared to be nearly black and traveling due south; both were moving at high speed. The two did not unite; but the lower layer, which was rolling and tumbling, eventually formed a typical thunderhead on the southeast corner of the main cloud, but lower and slightly in advance of it. This thunderhead, described by some as consisting of several layers, whirled rapidly counterclockwise, rolling and tumbling in all directions within the whirl. One observer said a southwest and a northeast wind seemed to meet head-on about this time and the clouds became still more agitated. Clouds were rushing into this center from all sides. No funnel appeared, but the whole cloud settled close to the earth, and a column of dust about 2 rods wide rose to meet it. The two never united and the dust column soon collapsed. All this time a roar was heard overhead.

The storm traveled southeastward and struck its first blow at Cottonwood Canyon (Fig. 1) shortly after 5 p. m. Its course from Cottonwood to Jeffrey Canyons was a zigzag one. It apparently traveled south, northeast, east, and southeast through this part of its course. Observers some miles north reported that the funnel seemed to whip back and forth in a great arc which they estimated to be 5 miles wide, writhing and twisting like a snake. From Jeffrey Canyon it traveled due east to the valley edge, then turned southeast, following the bluffs to the mouth of Hiles Canyon.

Its path was narrow, never over half a mile wide, while the zone of greatest intensity was only a quarter of a mile wide. At Tree and Gulch Canyons the center was about 500 to 800 feet wide, widening again east of Tree Canyon. About 2 miles east of Gulch Canyon it lifted, passed over four farmsteads, and dropped straight down on Tree Canyon. As it lifted the funnel broke into two parts,

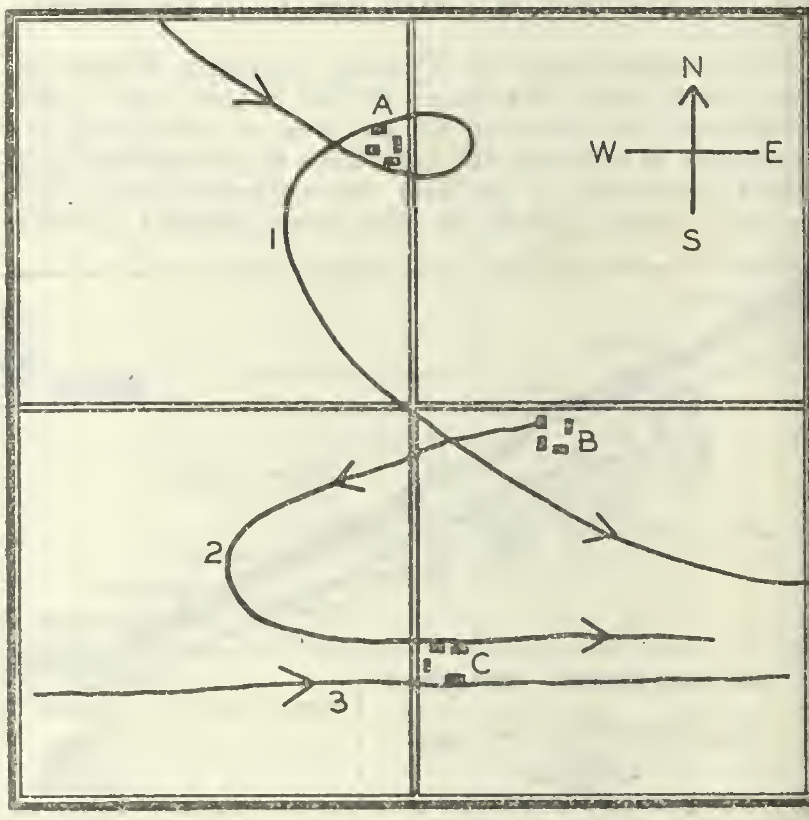

FIGURE 4.—Detail of tornado paths near McDowell farm southwest of Cozad

both whirling independently, the lower finally settling. The upper part gradually lifted and lagged behind until it was pointing due west, parallel to the surface of the cloud above, writhing and twisting. After rising the funnel was white, which seems to have been its usual color when not in contact with the earth. While up in the air no roar was heard and there was no wind on the ground. Mr. Quinn, at Tree Canyon, stood at the cellar door watching the storm approach and thought it was passing over. He estimated the funnel to be 400 feet above the ground. Suddenly the tail began to curl down, and when it struck the ground 300 feet west he jumped into the cellar. The storm lasted only a few seconds there, but he said it sounded like the battlefields of France. At Jeffrey Canyon Mr. Sytsma said it lasted four minutes. It struck Tree Canyon about 6 p. m.

Observers commented on the number of funnels formed, three or four of which were visible at a time.

Over a dozen funnels formed and dropped, but never reached the ground.

From Hiles Canyon the storm traveled east about 2½ miles, leaving the bluffs and moving out into the valley bottom. From this point almost to the end it moved in a southeasterly direction, staying in the valley until it reached a point due south of Lexington. There it passed up over the bluffs to the uplands, where it finished its course. The path varied in width from 1 to 2 miles, narrowing and widening until due south of Darr Bridge. The funnel rose and fell, being high enough much of the time to hit only the taller structures and trees. Due south of Darr Bridge its path narrowed quickly to a width of half a mile, and this was its maximum width for the remainder of its course.

For 2 miles due east of Hiles Canyon it was up in the air, hitting only the higher structures. Then it jumped due south a half mile, missing everything. At this point it dropped to the earth and moved east for 2 miles, wiping out nearly everything in its path. The funnel then jumped 1 mile southwest, doing little damage, but settling at that point to destroy one place.

During this part of its course the cloud continued to drop numerous funnels, some of which reached the ground. Observers testified that a funnel would drop, move due east 1 or 2 miles, and break up; then another funnel a half mile or a mile south or slightly southwest would form and repeat the performance. This story was supported by the lines of wreckage in the field which lay in a due east-west direction, sometimes overlapping a little and always paralleling each other, with little or no damage anywhere on the southward jumps. The path of the storm was in a southeasterly direction, but the lines of wreckage extended east and west.

According to observers, three funnels were in operation at almost the same time a mile north of the mouth of Midway Canyon. The wreckage seemed to support the story. The diagram, Figure 4, illustrates their movements.[1] Funnel 1 came from the northwest, passed over farmstead A, circled a few hundred feet east and came back over it, then turned and moved southeast over a cornfield between B and C. Funnel 2 dropped directly on B, traveled southwest a few hundred feet, and circled to the southeast, striking the north edge of C. Funnel 3 started dropping about 1 mile west of C, over which it passed, but high enough in the air so that it caught only the highest points at C. It hit the ground 100 feet east of the barn and destroyed a strip through a wheat field. The paths were all narrow, and funnels 2 and 3 disappeared about 1 mile east of C. The funnel circled in a similar manner at two other places, and three funnels struck at one other place.

From here the storm continued to the southeast, the path narrowing and the funnel striking the ground only here and there. Due south of Cozad the path widened again, but the point of the funnel remained high enough in the air to hit only the highest objects. South of Darr Bridge the storm became more intense, narrowed to a width of half a mile, and the funnel extended to the ground, destroying nearly everything in its path until it reached the bluffs of the Platte Valley.

As the storm moved across Gosper County it was joined by a cloud from the east and one from the southeast. Another funnel dropped, striking the ground near the Phelps County line, but did no damage west of the line. In Phelps County the storm was as concentrated and violent as in its earliest stages. It moved to the southeast over a path not more than half a mile wide, wiping out several farmsteads. The funnel never left the ground until it finally broke. About 6 miles northeast of Bertrand the funnel, traveling due east, passed over a farmstead. A quarter of a mile east of the farmstead the funnel made a half-circle turn to the left and came back over the same farmstead, moving due west. After passing the farmstead the second time it moved northwest about a mile and a half into a pasture, where it broke up. In both pastures the grass was scoured and beaten, much of it killed, and débris scattered around. It retained its violence to the last, completely wrecking a strongly anchored fence, where it disappeared.

At the end the funnel dipped and rose three or four times, the last time apparently breaking into two parts about halfway up. The lower half continued to whirl a short time and then, according to the account of witnesses, apparently exploded. The upper half lifted into the cloud and the storm was over, about 8 p. m.

The forward movement of the storm was slow. It traveled about 70 miles in approximately 2 hours and 45 minutes, giving it an average speed of about 25 miles per hour. Observers estimated its speed at 20 miles an hour. The rate of movement varied in different parts of its course. It traveled from Boxelder Canyon to Hiles Canyon, a distance of 24 miles, in one hour. It moved most rapidly during the middle part of its course, from Hiles Canyon to the bluffs, a distance of 28 miles, which it traversed in 45 minutes. Then it slowed down, traveling the last 16 miles in about one hour, the funnel striking the ground only during the last 10 miles.

Observers disagreed as to the direction of the wind before and after the storm. The majority of those questioned gave the direction as east or southeast before and west or northwest after the storm. All agreed that the wind was gentle before the storm, very strong for about 20 minutes after, and then gentle again. There was little or no rain before the tornado. The rain afterwards ranged from light to heavy, always with a sprinkling of large hailstones of the same type that fell at North Platte, and did not last over half an hour. The rest of the evening was unusually pleasant.

Except where it circled and struck twice, wreckage was distributed as would be expected. On the right, or south, side it was thrown to the east or northeast, forward and into the storm. On the left, or north, side it was thrown to the west and southwest, backward and into the storm. Wreckage that was carried any distance was carried to the east, usually not over half a mile. Trees and buildings were twisted counterclockwise. One barn was picked up, turned almost around, and, badly shattered, dropped in place. Buildings and posts were plastered with mud on the south and west sides, especially the south. The only exception to this was where the storm circled a place, and here the east face was plastered with mud. The mud was generally half an inch thick.

Examples of explosive action in the center of the storm were frequent. Windows were blown outward, in some instances disappearing without leaving a trace. In several buildings the walls, almost intact, blew outward and the roof dropped on the floor. In some cases roofs were partially or wholly removed, the walls remaining in place but bulged outward. Doors to caves were wrenched open outward. In one case the people reported difficulty in remaining in the cave due to the storm's suction.

[1] It was about 10 to 12 days after the storm before the writer reached the point where the 3 funnels described struck. The entire area covered by the funnels, with the exception of the farmsteads, was cornfield. As it had been cultivated since the storm, it was practically impossible to trace the paths of the storm in the field. The story is based on the account of 6 or 7 observers, some of whom were in the storm area and some a short distance to the side. All told the same story. They also pointed out the paths as given in the diagram, and a little wreckage was found, which seemed to substantiate the story.

At Conroy Canyon there is a cement-lined cistern, sunk level with the ground and covered with a loose board top. It is 16 feet long, 8 feet wide, and 8 feet deep, and before the storm had 4 feet of water in it. According to Mr. Ginapp, the center of the storm passed over it, removed half the top, and sucked out every drop of water. A lake with a surface area of 4 acres is located at the mouth of Tree Canyon, and out of this lake according to the testimony of a Mr. Quinn, who lives nearby, 2 feet of water disappeared.

Examples of scouring were found throughout the course of the tornado. In cornfields lister ridges 8 to 12 inches high were leveled. The best example of scouring was seen at Gulch Canyon. Before the storm all slopes were covered with a heavy growth of grass and low shrubs. Wherever the center struck, grass and shrubs were torn out by the roots, leaving the earth bare. In places even the earth was gouged out. Around this area everything was beaten down as if by a muddy torrent. The transition from this beaten zone to the

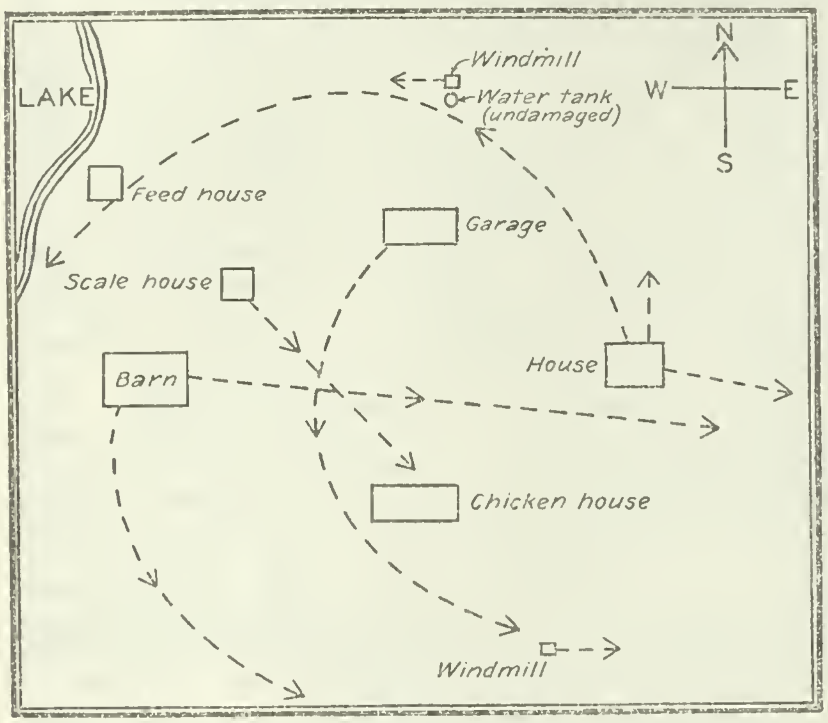

FIGURE 8.—Funnel a few seconds after striking Quinn ranch. The outer, lighter part is believed to consist of débris, dust, and water. Photograph by Mrs. Homer

undamaged zone was abrupt, taking place in a 2-foot strip. There was no leeward, protected slope. It swept up the west slope and down the east without missing an inch, no matter how sharp the crest. Pockets barely big enough to hold a man's body were thoroughly scoured out. Grass, looking as if a muddy torrent had rushed over it, was common throughout the storm area.

The center of the storm passed over an orchard of trees not over 10 feet high and stripped off every leaf and twig, but did not uproot, twist, or break a tree. Similar cases were common. In wheat fields the heads were frequently stripped off and the stem left standing.

Due south of Cozad the funnel passed over the farm of a Mr. Derrickson, destroying the upper part of the barn and the tops of trees and the windmill, but doing no damage to anything less than 30 feet above the ground. Mr. Derrickson was in the barn when the storm struck it. He felt the barn jump, stepped out into the yard, and walked 100 feet to the house, under the funnel which was about 30 feet above him. He said there was no noticeable wind in the yard, not even enough to stir the dust. Overhead it was black as night, and he could only see about 30 feet upward because of the dust and cloud of the funnel.

At one place a big truck was carried 300 feet up a hillside and destroyed. The tires, which carried 80 pounds pressure, were not punctured; but blades of grass were driven between tires and rims. The heaviest iron machinery was so twisted as to be made useless. A cement watering tank, 16 feet across and 2 feet high, was broken in half. One half was moved 20 feet eastward and shattered; the other, intact, was moved 10 feet; but a bag of feathers hanging by an ordinary string from a tree beside the tank was untouched. Brick and cement foundations only 2 feet high and set in the ground 6 inches were shattered. Two concrete blocks, weighing about 2,000 pounds each, were torn from their fastenings and rolled several feet. A combine was rolled and pushed a quarter of a mile and wrecked.

On one farm stood a garage in which the farmer kept his car and a 16-jar Delco light plant. A neighbor drove over to use his cave and parked his car beside the garage. The storm struck and the garage disappeared. The car in the garage suffered no damage except a broken wind shield, while the car outside was destroyed. The home from which the neighbor had fled was untouched. Mr. Sytsma said that 4 glass jars of the battery for the light plant were broken; the other 12 were taken from the shelf, 5 feet up, and placed on the cement floor without cracking any, but 3 were overturned so that the water escaped.

There were several places where almost every move of the center of the storm could be traced, but one of the best was about 4 miles northwest of the mouth of Midway Canyon. At this point stood a farmstead with several fine buildings and large feed yards surrounded by trees, the whole about a quarter of a mile square. The center of the storm passed over it and extended little, if any, beyond the trees. On the east side the trees were left pointing to the east and northeast, on the north to the north and northwest, on the west to the west and southwest, and on the south to the east and northeast. Toward the center they pointed in all directions, but plainly showed a counterclockwise twist. The buildings in the center were completely wrecked and the wreckage scattered to the east.

The Quinn ranch, at the mouth of Tree Canyon, also offered an excellent opportunity to study the movements of the air currents in the center of the storm. The farmyard is about 1,000 feet long from northeast to southwest. The funnel crossed it at right angles and was about 500 feet wide at this point. The north and south ends of the yards were not damaged, while the central portion was destroyed. Figure 5 shows the lines on which the wreckage was distributed by the storm. All wreckage not dropped in the yard was carried eastward for distances not exceeding half a mile. Wreckage from the house was scattered in three directions. The chimney was thrown to the north, the walls, roof, and most of the furniture were carried along a curved line to the northwest, while the floor was carried eastward. Some of the furniture on the floor dropped into the basement. Twenty-two tons of baled hay in the barn were carried eastward, while the rest of the wreckage was scattered along the curved line to the southeast. The wreckage of the feed house was found 1,000 feet to the east. The path of the wreckage from the chicken house was not determined.

Trees varied noticeably in their ability to withstand the storm. Cottonwoods were damaged the most, while pines and cedars suffered the least.

The damage done by the storm was estimated at about $200,000, which no doubt was moderate, as there were several farms where the loss ranged from $10,000 to

FIGURE 5.—Distribution of wreckage at the Quinn ranch at the mouth of Tree Canyon, about 6 miles southwest of Gothenburg

FIGURE 6.—Funnel approaching Quinn ranch at Tree Canyon. View taken by Mrs. Ray Homer from a point one-half mile east of the funnel

FIGURE 7.—Funnel at the moment of striking the Quinn ranch. Photograph by Mrs. Homer

$20,000. Only one life was lost and five people injured. The low loss in life and property was due to three causes. The storm struck only rural sections throughout its course. It moved slowly, about 20 miles an hour, making it easy to get out of danger. It was visible for miles, and nearly everyone had watched it for at least 15 minutes before it struck. Word was also sent in advance by telephone.

The storm seems to have been due to conditions in the upper atmosphere, rather than unequal or extreme heating of the earth's surface. A check of the pressures, temperatures, and wind velocities reported from the stations surrounding North Platte revealed only slight differences. There was no hot wave before the storm; in fact, the week preceding had been rather cool. Strong contrary winds were observed tossing the clouds at different levels before there was any sign of a tornado, while it was nearly calm at the ground. One observer said that it seemed to him as if a southwest and a northeast wind had met head-on overhead and started a whirl which began to enlarge and suck the clouds in toward it. The large number of funnels formed would indicate that a number of eddies existed in the upper atmosphere, but not all had strength enough to reach the ground. Some observers said that the tornado cloud seemed to consist of several layers at first. The make-up of the hailstones would indicate the presence of several levels of air with different temperatures.

HAIL DAMAGE IN IOWA

By CHARLES D. REED

[Weather Bureau, Des Moines, Iowa]

Assessors in Iowa are required to ask each farmer on about 210,000 farms as to the amount of hail damage to crops on his farm the preceding crop season. These data are tabulated and summarized by the weather and crop bureau of the Iowa Department of Agriculture.

Eight years of these data are available at the close of 1930. In that period the average annual hail loss in the State was $4,513,760, while the average value of the crops at risk was $391,483,456. The greatest loss, $7,975,686, was in 1925, and most of it occurred in the storm of August 18, extending from the southeast corner of Poweshiek and the southwest corner of Iowa Counties, almost due southeastward about 60 miles across Keokuk, Washington, Jefferson, and Henry Counties and into Lee County. The total damage in this storm was approximately $5,000,000, making it probably the most destructive in the history of the State. The least damage was $1,598,963 in 1930.

The greatest county damage was $1,076,280 in Woodbury County in 1929, and the greatest township damage was $321,380 in Liberty Township, Keokuk County, in 1924. The average number of townships reporting hail damage in the past eight years is 563, or 35 per cent of the total number of townships. In 1929, only 387 townships, or 24.1 per cent, reported hail, which is the least in the eight years, but the damage in these townships was rather intense, so the total was greater than in 1930.

Data are insufficient to work out definite zones of damage, but it now appears that the counties along the Missouri and Big Sioux Rivers and those adjacent are more subject to hail than other portions of the State, while a good many counties in southeast Iowa, particularly Davis, are nearly immune. In the 8 years, 24 counties had one or more years with no damage; 14, mostly in the southeast, had only 1; 4 counties, Dallas, Henry, Louisa, and Monroe, had 2 years; 5 counties, Des Moines, Jefferson, Lee, Van Buren, and Wayne, had 3 years; and 1 county, Davis, had 4 years without hail damage.

In the eight years, 159 townships, or about 10 per cent of the area of the State, reported no hail. It was found that in several cases considerable damage was reported by monthly crop reporters and others in some of these 159 townships from which the assessors reported no damage. This discrepancy may be explained by the fact that crop reporters make their reports immediately after the storms occur, and at certain stages crops, especially corn, in a favorable season, have been known to largely recover from what at first appeared to be almost total destruction. Some months later when the assessor visits the farmer, the crop harvested is so nearly normal in yield that the farmer has forgotten all about the damage.

On the other hand, hail damage is so extremely localized, being large on one farm and amounting to nothing on an adjoining farm, that the actual acreage that escaped damage in the eight years is no doubt greater than the 10 per cent shown by using the township as a unit, and may be twice that amount.

It is recognized that the fluctuating values of crops of nearly equal quantity, or the inflation and deflation of the dollar, makes the dollar an unsatisfactory unit for measuring and comparing hail damage over a long period of years; yet it is convenient; a more complicated method might break down the cooperation of assessors and farmers; and eventually refinement may be effected by applying some commercial index number. The per cent of damage requires no such refinement. It is found by dividing the total damage (times 100) by the total value of crops at risk. In this 8-year period it averaged 1.15 per cent, the greatest being 1.99 per cent in 1925 and the least 0.50 per cent in 1930.

Further details are shown in the accompanying table.

Experience of hail insurance companies shows a larger per cent of damage than these figures indicate, for the reason that it is easy to write policies in a territory where devastating hail storms are of almost annual frequency, and relatively hard to write policies in a county like Davis, where damage is rare. The rates of the companies must therefore be basicly higher and must, in addition, include the cost of getting the business, adjusting the losses, setting up reserves, maintaining offices and employees, and general overhead expenses.

If this line of inquiry is continued long enough, possibly when 20 years of data are available, a more satisfactory scale of county or even township rates for hail insurance may be worked out.

Hail damage in Iowa

[Reported by township assessors]

Year	Damage and risk			Area of damage		Largest county damage		Largest township damage		Counties reporting no damage
	Total damage in State	Total amount at risk	Per cent of damage	Number of townships reporting damage	Per cent of all townships in State	Amount	County	Amount	Township and county	
1923	$2,319,507	$382,987,102	0.61	451	28.0	$233,336	Poweshiek	$70,094	Bear Creek, Poweshiek County.	Dallas, Davis, Des Moines, Dickinson, Guthrie, Jefferson, Lee, Louisa, Van Buren, Washington, Wayne.
1924	6,903,909	422,087,377	1.64	598	37.1	690,259	Keokuk	321,380	Liberty Keokuk County.	Monroe, Wayne.
1925	7,975,686	401,371,307	1.99	748	46.5	592,800	do	189,230	English River, Keokuk County.	Davis.
1926	2,342,187	355,664,129	0.66	465	28.9	415,020	Webster	175,225	Roland, Webster County.	Iowa.
1927	5,064,717	380,753,693	1.33	664	41.2	442,305	Clinton	155,150	Eden, Clinton County	Davis, Dubuque.
1928	6,363,932	439,206,488	1.45	779	48.4	558,966	Plymouth	189,147	Magnolia, Harrison County.	Henry, Jefferson, Louisa, Van Buren.
1929	3,541,179	429,093,048	0.83	387	24.1	1,076,280	Sioux	203,400	Lincoln, Sioux County.	Clay, Davis, Des Moines, Lee, Marion, Palo Alto, Wayne, Winnebago.
1930	1,598,963	*320,704,507	0.50	410	25.5	551,818	Woodbury	83,532	Liston, Woodbury County.	Clarke, Clinton, Dallas, Des Moines, Henry, Jefferson, Jones, Lee, Mahaska, Mills, Monroe, Van Buren.
Average	4,513,760	391,483,456	1.15	563	35.0	570,098		173,395		

*Amount at risk, 1930, preliminary estimate, subject to change.

MELON FROST FORECASTING IN THE UMPQUA VALLEY, OREG.

By Edgar H. Fletcher

[Weather Bureau Office, Roseburg, Oreg., April 27, 1931]

INTRODUCTION

Since it occurs to the writer that forecasting frost for the benefit of commercial cantaloupe growing may be a rather new departure in the field of frost protection, a brief outline of the practical application of this service to the melon industry in the Umpqua Valley is presented, with special reference to the part played by fog formation.

CONDITIONS FAVORABLE FOR CANTALOUPE PRODUCTION

The lowlands in the isolated valleys along the South Umpqua River in the general vicinity of Roseburg, Oreg., are being utilized for the growing of cantaloupes of superior quality. The three factors of primary importance—soil, temperature, and moisture—upon which the successful growing of cantaloupes depend are properly correlated here to produce quality and quantity.

The soil of these bottom lands is of silty loam, from 10 to 15 feet deep on gravel through which the river runs, and with a water table so high as to preclude the necessity of irrigation. The vines root down 5 or 6 feet and depend on subsoils moisture, which is supplied by generous winter rains, the summer season being almost rainless. Thus the unirrigated growth, together with the long growing season of cool nights and warm days, not only develops an extremely high sugar content but improves the flavor and keeping qualities, so that melons can be picked fully ripe for shipment almost any distance. The best and finest flavored crops are grown in the years when no rain falls from the time of germination to the end of harvest.

FROST PROTECTION NEEDED

The harvesting season begins about August 15 and continues through the greater part of October. But there is the ever-present danger of frost during the second half of this period; and since it is in the second half that all the growers' profits lie, it stands the grower who wishes to safeguard his season's labor and results therefrom well in hand to consider some method of frost control, especially since the vines will continue to produce until killed by frost.

Experiments, though somewhat crude, in the fall of 1929 clearly demonstrated the fact that frost-control work can be successfully and profitably accomplished on late-maturing melon fields. It occasionally happens that an early fall frost occurs when a large portion of the crop is still unmatured. To protect against a single September frost may be the means of prolonging the growing season for two or three weeks, and just at the time when the market is becoming more favorable. After the coming of the fall rains there is usually sufficient soil moisture to produce fog in the early mornings on radiation nights, thus affording a natural protection against frost damage. But frost hazard is great under any barometric condition with low atmospheric moisture and clear nights.

EFFECT OF WIND

The wind movement, being extremely light in these more or less inclosed valleys, is not usually an important factor to be considered; neither is air drainage, as the valley surfaces are nearly level. However, a change in wind direction during the night to northerly or easterly has the effect of lowering the dew point and consequently preventing the formation of fog which may have been indicated at 5 p. m., especially if clearing does not occur until after that hour.

FOG AN IMPORTANT FACTOR

An essential prerequisite to frost and minimum temperature forecasting in this region is the foretelling of the occurrence of morning fog, together with the degree of density, and the approximate hour of beginning, since occasionally there will be some damage before the fog begins to retard the fall in temperature.

Fog conditions can be determined with great accuracy from the 5 p. m. dew point and relative humidity in connection with the chart shown in Figure 1. This chart shows under what values of 5 p. m. dew point and relative humidity fog has occurred on radiation nights for the fall season at Roseburg during the past 22 years when the minimum temperature was 40° or below. In using the chart, if the hygrometric values fall to the left

of the free-hand-drawn curved line, a clear sky with no fog is indicated, but if to the right of the curve, fog or cloudiness is clearly indicated; furthermore, the character of fog and the approximate hour of beginning can be determined by the departure of the values from the curve. Additional charts may be prepared to show these relationships.

It will be noted that the chart is quite dependable near the middle of the curve, where most of the observations fall. The comparatively few occurrences near the ends of the curve are rather unimportant cases that either occurred late in the season or were followed by minimum temperatures slightly above 40°, and were added to show the hyperbolic trend of the curve. This chart is highly efficient for the purpose intended.

As past records show that fog occurs on a large percentage of radiation nights, there are but comparatively few occasions in a normal year when frost protection is actually needed, as fog often performs this function automatically. But it is on these few nights, if early in the season, that the growers desire to be advised. There is an occasional year when no frost damage occurs during the main producing season.

Figure 2 is a section of the thermograph trace at the temperature station of Dillard, Oreg., on two consecutive nights, showing the rising tendency in temperature after the formation of fog near or soon after midnight. A slight secondary fall occurred with the diminution of fog near sunrise.

The dew point alone will not serve to determine the occurrence of fog as accurately as it will in conjunction with the relative humidity, because in the latter case a factor of the current temperature is also introduced. For instance, an evening dew point as low as 32° may be followed by dense fog before morning if the relative humidity is comparatively high, while, on the other hand, a dew point of 45° may not cause fog if the relative humidity is low. This inverse relationship is well shown in Figure 1.

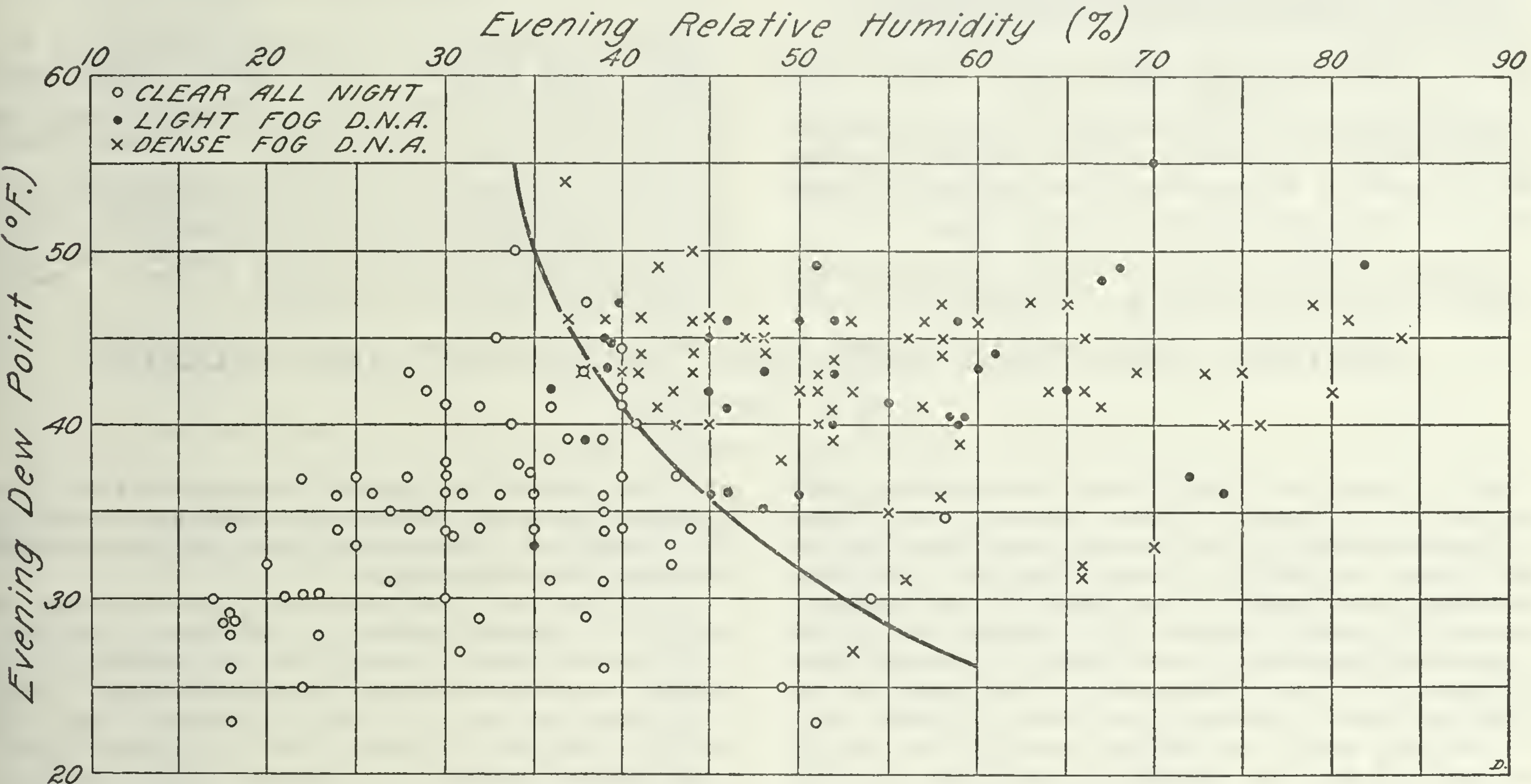

FIGURE 1.—Relationship between the 5 p. m. dew point and relative humidity to the state of the ensuing weather—whether clear all night or fog after midnight—on radiation nights at Roseburg, Oreg., during the fall season of September, October, and part of November for the years 1909–1930, when ensuing minimum temperature was 40° or below. The curve separates hygrometric data when the weather remained clear all night from those when fog occurred

MINIMUM TEMPERATURE FROM FORMULA

When it is evident that the sky will remain clear throughout the night, the ensuing minimum temperature is determined by use of a hygrometric formula developed after the Young method (*1*) (*2*), which has proven quite successful; but the result is checked against a Nichols free-hand curve (*3*) on a hygrometric dot chart based on a long period of record, and in some instances a further slight correction is made.

MINIMUM FROM CURRENT TEMPERATURE

In this locality the 5 p. m. temperature alone, as proposed by Nichols (**4**), does not seem to be a reliable index to the morning minimum; the moisture factor must be given much weight. Minimum temperatures of 32° or below have occurred frequently on radiation nights with the 5 p. m. temperature varying on different occasions from 45° to 75°. An interesting instance occurred on September 6, 1929; the temperature at 5 p. m. was 80°, the dew point 30°, and the relative humidity 17, but before morning the temperature had fallen to 42° at the Weather Bureau, causing a light frost with some damage to melon foliage in the low valley sections. This range in temperature was caused by cooling from local radiation under favorable conditions of low humidity and practically no wind, calm having been recorded for five consecutive hours after midnight.

VARIATION FROM WEATHER BUREAU KEY STATION

Minimum temperatures on clear nights in the melon districts have been found to be from 6° to 8° lower than at the Weather Bureau key station. However, the variation is somewhat irregular, depending upon local conditions, but as a general rule, when a minimum of 40° or lower is expected at the Weather Bureau, frost will occur along the lower river bottom lands, provided in all cases fogs do not form during the night. As yet no

extensive temperature survey has been made of the district. Thermographs have been exposed only during two frost seasons at two stations in separate regions. Some variation in temperature between these stations has been noted on nights with varying local fog conditions.

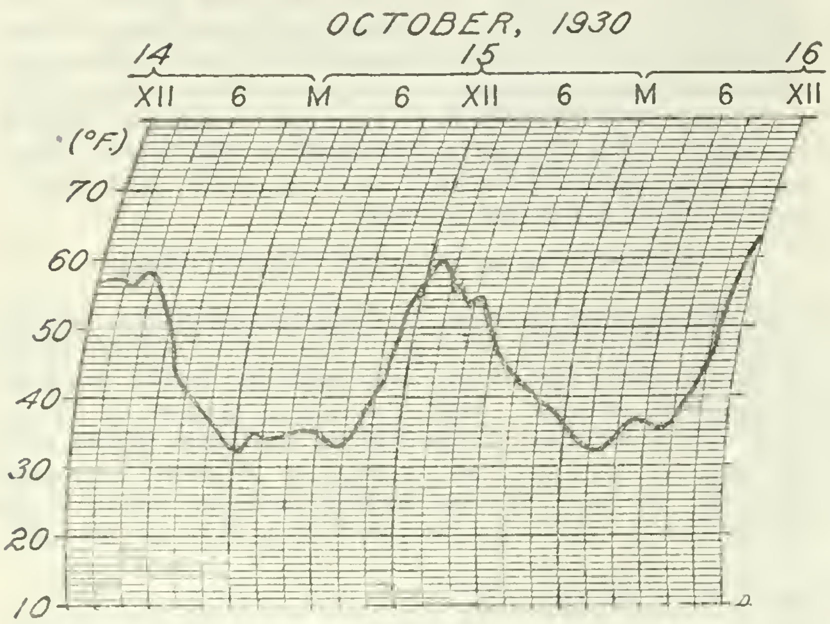

FIGURE 2.—Thermograph trace, Dillard, Oreg., October 15-16, 1930, showing the effect of fog in retarding temperature fall

VALUABLE AID AT PLANTING TIME

Another important service that the Weather Bureau renders the melon industry is at planting time in the early spring, when the weather is still much unsettled. As cantaloupe seed will germinate only under favorable weather conditions, planting must be avoided just previous to a cold, rainy period or one with strong, drying northerly or easterly winds. The kind of weather that is expected to prevail not only determines the time but also the depth the seed should be planted for best results. The growers state that the availability of this service has done much to take one of the major risks of melons in the Umpqua Valley—that of uncertain stands—from the industry. The crop must be started as early as possible after the frost danger is past in the spring in order that the maturing season may be well advanced before the coming of cooler fall weather, with its possibility of frost. Hence, frost protection in the spring is not a factor to be considered.

The aid the Weather Bureau has been able to give the melon growers has played no little part in the development of this rapidly expanding industry in this valley.

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WEATHER CONDITIONS AFFECTING THE PORT OF NEW ORLEANS

By W. F. McDONALD

[Weather Bureau, Washington, May, 1931]

Out of a number of years' experience with the public contacts of the Weather Bureau Office at New Orleans in connection with requests for information about weather and climatic conditions, I have formed some judgments regarding those features of the climate that appear to be of most practical concern to the business of the port. A detailed discussion of the records supporting these judgments can not be presented at this time, but the following general statements may have suggestive value.

1. General weather conditions, especially with respect to wind and fog, are decidedly favorable to commerce through the port of New Orleans. Average wind velocities are low, only 7.5 miles per hour for the year, and less than 9 miles per hour in March, the month of highest average wind. Maximum velocities exceed 26 miles per hour on an average of only 15 days per year, and maximum velocities of 45 miles per hour have been exceeded in only 2 of the 12 months, namely, August and September, when tropical storms have caused storm conditions producing higher wind velocities. Fog frequency affecting the water front is not fully represented by the records taken at the Weather Bureau office, but fogs of a duration sufficient to delay commerce more than a day are of relatively infrequent occurrence, and accidents due to fog are uncommon. River fogs are of somewhat greater frequency and duration than those which occur at moderate distance from the river, because the cold water coming down from the north during spring months contributes to highly localized fog formation when warm waves bring moist southerly currents inland from the Gulf to be chilled on contact with the cold river surface. The shallow nature of this localized river fog permits shipping to be moved at times from masthead lookout when dense fog conditions prevail at the level of the deck. Most cases of fog delay are measured in terms of a few hours only.

2. Examination of the records of storms affecting the port of New Orleans indicates that tornadoes are relatively unimportant—indeed, almost unknown. Only one authentic tornado has occurred in the immediate vicinity in 25 years, the one case being in October, 1906, when damage estimated at $300,000, with 21 persons injured, but no deaths, occurred in a tornadic path 4 miles long. Local storms of damaging violence, several of which may have been very small tornadoes or incipient tornadoes, have been recorded on seven other dates in 35 years of records for that vicinity, with damages running over $25,000 in only three of the seven cases.

Ten tropical cyclones are recorded in the Gulf region in 25 years, but only a few of these storms have directly affected the port of New Orleans to more than very minor degree. Shipping bound to or from New Orleans has been lost in a few instances; however, the losses at sea in this period have been remarkably few in the Gulf region, and I dare say less in proportion than the losses to North Atlantic commerce due to extratropical storms.

Only two storms in the weather history of the port of New Orleans during the last 35 years have been weather events of serious magnitude. The greatest damage resulted from the tropical hurricane of September 29, 1915, with an earlier severe but less damaging hurricane of September 20, 1909. Even in these cases, however, the principal maritime losses were confined to the smaller craft, such as tugs, barges, derricks, small river steamers, etc.

There is no doubt that under modern conditions, which permit the Weather Bureau to issue accurate warnings of the existence and progress of hurricanes while they are still at sea, the interests concerned with storm hazards can do much toward safeguarding shipping and commodities from threatened damage. There is also no doubt that a repetition of a hurricane along a track to bring the center inland from the Gulf near and slightly to westward from New Orleans will again cause much damage in spite of all possible precautions. Nevertheless, the storm hazard, measured either in terms of frequency or in percentage of total values lost by storm, is relatively low.

3. The physical location of the port of New Orleans, many miles from open Gulf waters, fully protects the harbor from damage by storm tides. In the 1915 hurricane the level of the river was raised about 6 feet, due to the effects of the tide, but the fluctuation of river levels by reason of the annual flood flow is very much greater than this amount, and ranges upward to 20 feet in a year of large flood.

The fluctuation of 15 to 20 feet in the annual course of river stages does offer some disadvantages to commerce, and these changes in river level, resulting, as they do, from weather conditions in the valley above, may be classed as a climatic characteristic of the port. Local changes in the river bottom accompany the alternation between flood and low water. The advent of extreme low water each year almost invariably calls for considerable dredging at wharf sides and in slips in locations where there is an accumulation of sediment during high stages. In other places floods regularly produce a damaging erosion that involves occasional rebuilding of wharves and levees or calls for costly protective measures. These matters are of course not direct charges upon the business of the port, as the costs are covered by State or Government funds, but the expenditures are properly chargeable to the overhead of port operations.

4. The high total of annual precipitation might be thought to indicate considerable interference with the business operations and commerce at New Orleans. This is not the case. Rainfall is more generally of the intense shower type than of the long-drawn-out character more commonly experienced in cooler climates. The highest hourly frequency of rainfall in any month is 10 to 14 per cent in the warmer part of the day, from June to September. The hourly frequency does not exceed 8 per cent in any other month of the year, and is as low as from 1 to 3 per cent in many hours. Excessive precipitation is less damaging to commerce over the wharves than in other parts of the city, because the river banks are the highest land surfaces, with the slope gradually dropping away from the river, as is common in all true delta regions. Drainage is excellent.

5. While rainfall may thus be shown to be a minor factor in the flow of commerce through the port of New Orleans, it must be admitted that there is considerable difficulty in protecting some commodities from damage by reason of the high *absolute* humidity of the air. Due to the higher average temperatures than those prevailing in other major ports of the United States where *relative* humidities are quite similar, the atmosphere at New Orleans actually carries a much larger quantity of water vapor. Packaged foods, such as cereals, granulated and powdered sugars, canned goods, and some other commodities, as charcoal and chemicals, subject to hygroscopic influences, may suffer considerably in storage and handling due to this feature of the climate.

On the other hand, some commodities are probably handled to advantage because of the higher humidities. Cotton, for instance, received at New Orleans from the more arid regions of the Southwest gains appreciably in bale weights by absorption of moisture, and this change represents gain to the buyer at arid loading point who sells on the weight at New Orleans.

Two other specific examples of the troublesome consequences of high absolute humidity affecting some commodities handled at New Orleans will give point to this phase of the climate in its effects on commerce. Granulated sugar, especially in bags, but to a considerable extent also in wax packages, cakes badly, especially in winter. The remarkable intensification of this problem in winter was difficult to explain on general grounds, because the absolute humidities are of course highest in summer. The cost of handling and regranulating spoiled packages was sufficiently serious to set several of the large sugar companies to a scientific investigation of the underlying conditions. The investigation revealed that the sugar caked most seriously, not when the humidity remained steadily high but when high humidity was followed by a spell of abnormally dry weather. Such variations can only occur at New Orleans with the alternation between warm and cold wave type conditions characteristic of the colder part of the year. The explanation appears to be something like this: High absolute humidity increases the natural moisture film on the sugar grain to an extent which may reach the point of some coalescence between particles in contact. The dehydration attending a few days of unusually low humidity then results in some recrystallization of this sugar film, which cements the granules into a caked mass.

The other instance, of similar obscure nature, occurred in connection with a series of fires attributed to spontaneous combustion in car-lot charcoal shipments moving to New Orleans from a point 500 miles in the interior.

A business of $100,000 annually was threatened with extinction by the increasing insurance rates following the large number of fires experienced in transit. Again a technical investigator was placed on the trail, and the trouble was located and cured. Charcoal, fresh from the furnaces, is highly hygroscopic and heats upon absorption of moisture. Therefore, the shipments which were loaded at relatively low humidity absorbed enough moisture from the more humid coastal atmosphere to set up spontaneous combustion from the heat generated in the interior of some of the carloads. A positive cure for the evil consisted in wetting down the fresh charcoal when it went from the furnaces into the loading bins, where it cured for a few days prior to shipment.

6. Temperature influences on the commerce of New Orleans are in the main unimportant except in connection with one major item of imports, namely, bananas. The critical temperature for bananas is about 40° F., as the fruit does not ripen properly if it has been chilled below that degree of temperature. Unloading of banana cargoes is an open-air process, which is greatly hampered when temperatures fall below 40° and must be stopped entirely when the temperatures fall toward freezing. Average conditions at New Orleans are very favorable for this commerce, as few occasions demand delay or special precaution in transfer of bananas from ship to car.

SUMMARY

Climatic conditions bearing upon the commerce of the port of New Orleans are more favorable than otherwise, with the sole exception of the hazard of severe tropical storm, which is infrequent, having occurred only twice in the last 35 years.

NOTE ON J. F. BRENNAN'S METHOD OF DETERMINING THE ALTITUDE IN THE ATMOSPHERE ABOVE SEA LEVEL WHERE THE FREEZING POINT OF WATER OCCURS [1]

By ANDERS ÅNGSTRÖM

[Meteorological-Hydrographical Office, Stockholm, Sweden, June, 1931]

As regards the very simple method described by J. F. Brennan[1] for determining the position of the zero isotherm in the free atmosphere, the present author may be allowed to add some remarks as a consequence of a number of experiments and tests carried out under his supervision at the Meteorological-Hydrographical Institute at Stockholm. From these experiments I am inclined to doubt the practical applicability of the method of Mr. Brennan, at least in the simple form described in the paper.

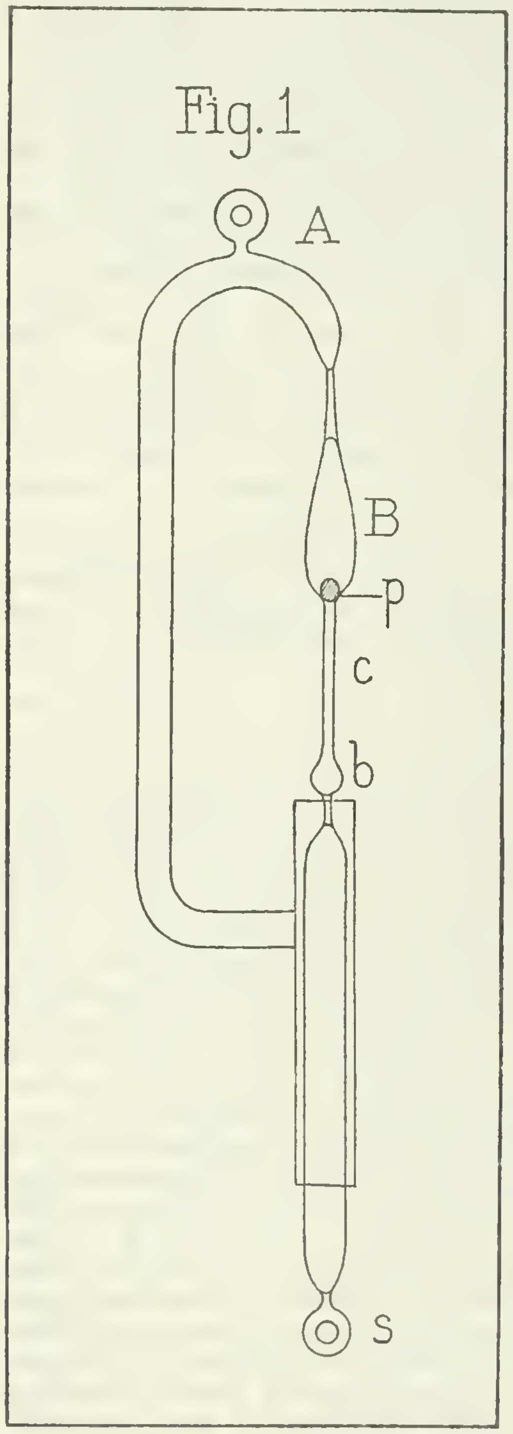


FIGURE 1.—Device for determining the height of the zero isotherm in the free atmosphere

The method is founded upon the expansion of water at freezing. The expansion is used for releasing, at the height at which freezing occurs, a paper pendant from a pilot balloon and the moment of the release is noted. For further details I may refer to the original note of Mr. Brennan.

The great difficulty in the practical application of this method is due to the fact that water does not under ordinary conditions, when no ice crystals are present, freeze at a fixed temperature. Inclosed in a small vessel of glass or metal and cooled down below zero, water freezes at times between −0° C. and −3° C., but may sometimes be cooled down to about −7° to −8° C. without freezing. In shaking the vessel or through blowing small air bubbles through the water we may reduce the probability for a considerable undercooling, but the fact remains that the water even under these conditions may freeze at temperatures varying by a couple of degrees.

Figure 1 shows the design used in our experiments. The water is inclosed in the small glass bulb *b* and in the small capillary tube *c*, connected to the glass bulb. Cooling the system below 0° C. we find that the water will at first freeze in the tube; when the water some moments later freezes in the bulb the capillary is broken and the signal attached at *s* is released from the balloon attached at *A*.

A large number of experiments were carried out in order to prevent the water from undercooling. An automatic shaking device was designed where the vertical movement of the balloon was used for driving a little "shaker." We also investigated whether the addition of powdered substances like fine grains of metals, etc., would help, but with small effect.

Considerable progress however was obtained through stirring the water in order to produce small air bubbles. It seems as if very small air bubbles present in the water would prohibit further undercooling. The smaller the air bubbles, the higher their internal vapor pressure, and the more effective they seem to be in prohibiting a considerable undercooling. The difficulty in the practical application, however, is chiefly the following: When small air bubbles are produced at a certain temperature above zero, the cooling of the water will have the consequence that air will be absorbed and at the temperature at which the water ought to freeze we run the risk that no air bubbles are present. On the other hand too large air bubbles have no or very little effect. Practically, the difficulties are so great as to make this method of preventing undercooling almost useless.

The final arrangement, which, in spite of its effectiveness, is lacking considerably in practical elegancy, consists in letting a part of the water be frozen at the start in order that undercooling may be impossible. For that purpose a second glass bulb *B* (fig. 1) was added, and the freezing of the water in this larger bulb was effected through dipping this part of the glass system, before the release of the pilot balloon, in a Dewar bottle containing a solution of solid carbon dioxide in alcohol. By including a small grain of lead *P* in the bulb *B* ice was caused to form around *P*, in the lower parts of the bulb, in immediate contact with the water in the capillary. The whole glass system was made at a cost of about half a dollar a piece at the Grave Instrument Co., Stockholm.

Experiments with this device made it clear that we may in this way easily freeze the water at a temperature variable within not more than about ±0.5° and generally at about −1° C. Trials, in which two pilot balloons were sent up in tandem and one of them released at the breakage of the glass, gave the same result, comparisons being made with the results of meteorograph ascensions. In spite of some inconveniences inherent to the arrangement of partly "prefreezing" the water, the method undoubtedly includes some advantages, and may probably be considerably improved.

During these experiments the author had the able assistance of O. Nauclèr, civil engineer, to whom sincere thanks are due.

[1] MONTHLY WEATHER REVIEW, February, 1931, vol. 59, p. 75.

ANALYSIS OF THE PRECIPITATION OF RAINS AND SNOWS AT MOUNT VERNON, IOWA

By LYLE L. COTTRAL

[Cornell College, Mount Vernon, Iowa]

Under the direction of Dr. Nicholas Knight, Cornell College, Mount Vernon, Iowa, has for the last 20 years carried on an analysis of the rain and snow precipitated here. The results of much of this work have been published in periodicals of a scientific nature.

The precipitations are collected in clean granite pans, away from trees and buildings, and stored in glass stoppered bottles. The town has no factories and, exclusive of the college, has a population of about 1,700. The sulphuric acid found comes therefore mainly from the coal used in private heating plants. It has been found necessary to deduct 3.55 parts per million from the reading to allow for the formation of the color in the test for the chlorides. The precipitations come from the east or the south, which signify that the salt is carried by the winds from the Atlantic Ocean or the Gulf of Mexico. Due to some criticism special care has been taken in the analysis of the chlorides, which, after considerable work, we have reason to believe correct. The phenoldisulphonic acid method was used with the nitrates. All of the samples were colorless.

The methods used in the analysis are taken from the Standard Methods of Water Analysis, sixth edition, published by the American Health Association.

TABLE 1

No. of sample	Date of precipitation, 1930	Amount	Rain or snow	Nitrates	Nitrites	Free ammonia	Albuminoid ammonia	Sulfates	Chlorides
1	May 5	0.6	Rain	0.04	0.0001	0.056	Traces.	------	14.2
2	May 6	0.25	do	0.06	Traces.	0.04	Traces.	------	7.1
3	June 5	1.5	do	0.06	Traces.	Traces.	Traces.	------	15.62
4	June 13	0.25	do	0.32	Traces.	Traces.	------	------	21.30
5	June 14	0.35	do	0.64	Traces.	Traces.	0.0032	------	------
6	June 15	3.	do	0.64	Traces.	Traces.	Traces.	------	14.2
7	June 25	0.2	do	0.32	0.0002	Traces.	------	------	24.85
8	June 30	0.45	do	0.64	0.0004	0.054	Traces.	------	28.40
9	Sept. 25	0.25	do	0.64	Traces.	0.08	Traces.	------	------
10	Sept. 26	2.0	do	0.64	Traces.	0.08	------	------	38.50
11	Oct. 6	0.25	do	0.32	0.004	------	------	------	31.95
12	Oct. 7	1.90	do	0.64	0.0001	Traces.	------	------	31.95
13	Oct. 16	0.75	do	1.28	0.001	0.064	0.931	0.012	31.95
14	Oct. 29	0.20	do	0.64	Traces.	0.072.	------	------	17.75
15	Oct. 30	0.20	do	0.56	0.0002	0.0752	0.0416	------	------
16	Nov. 15	0.25	do	0.64	0.0017	0.08	0.120	0.044	24.95
17	Nov. 16	1.00	do	0.64	0.0001	Traces.	Traces.	------	24.95
18	Nov. 20	0.4	do	1.28	0.001	0.200	Traces.	------	------
19	Nov. 25	4.	Snow	0.32	Traces.	0.078	0.0496	------	37.15
20	Nov. 30	0.6	Rain	0.64	0.0008	0.0288	0.0160	------	------
21	Dec. 5	0.7	do	0.32	0.001	0.0272	Traces.	------	14.2
22	Dec. 13	5.00	Snow	0.64	Traces.	0.016	0.0144	0.024	17.75
23	Dec. 18	4.	do	0.64	0.0006	0.0192	0.0048	0.146	------
24	Jan. 18	4.	do	0.64	0.0002	0.064	0.0032	0.428	3.55
25	Feb. 6	3.	do	0.64	0.001	0.144	0.192	0.218	10.65
26	Mar. 7	4.	do	1.28	0.0004	0.72	0.04	0.184	3.55
27	Mar. 24	0.3	Rain	0.56	0.0004	0.448	0.98	0.104	3.55
28	Mar. 27	4.	Snow	0.64	0.0004	0.04	0.64	0.068	3.55
29	Mar. 28	15.0	do	0.48	Traces.	0.04	0.04	1.68	7.10
30	Apr. 3	0.15	Rain	------	0.0544	0.800	0.490	3.4	7.10
31	Apr. 9	0.10	do	0.64	0.0128	------	------	0.30	10.65
32	Apr. 16	0.4	do	1.28	Traces.	1.60	0.640	1.4	3.55
33	Apr. 19	0.8	do	0.74	0.0001	0.52	0.245	2.00	3.55
34	Apr. 20	0.5	do	0.64	Traces.	1.200	0.160	1.30	3.55
35	Apr. 21	0.5	do	0.64	0.0001	0.32	0.136	3.60	3.55
36	May 5	0.1	do	0.64	0.001	0.89	0.490	2.00	7.10
37	May 9	0.5	do	1.28	0.0002	0.544	Traces.	2.00	3.55
38	May 11	0.4	do	0.65	0.0004	0.36	Traces.	3.70	3.55
39	May 19	0.4	do	1.28	0.0007	0.64	0.260	------	7.10
40	May 29	------	do	0.32	Traces.	0.04	Traces.	------	7.10
41	June 5	0.25	do	0.64	0.016	------	------	------	10.65
42	June 6	0.75	do	0.64	0.0001	0.08	Traces.	------	3.55
43	June 7	0.08	do	0.64	0.0002	0.98	Traces.	------	3.55

12 inches of snow = 1 inch of rain.

The results of the school year 1930–31 are expressed in Tables 1 and 2. The numbers indicate the parts of the various substances in a million parts of water.

TABLE 2.—*Data from Table 1 converted to pounds per acre*

[1 inch of rain over 1 acre=226,875 pounds]

No. of sample	Nitrates	Nitrites	Free ammonia	Albuminoid ammonium	Sulphates	Chlorides
1	05.445	00.680	07.62	Traces.	------	01.9312
2	03.803	Traces.	02.268	Traces.	------	00.40257
3	20.418	Traces.	Traces.	Traces.	------	05.304
4	18.150	Traces.	Traces.	------	------	01.20771
5	50.819	Traces.	Traces.	00.244	------	------
6	43.522	Traces.	Traces.	Traces.	------	09.656
7	01.452	00.9075	Traces.	------	------	01.12344
8	06.534	04.080	05.508	Traces.	------	02.896
9	03.630	Traces.	04.536	Traces.	------	------
10	29.040	Traces.	36.300	------	------	17.48
11	18.150	22.680	------	------	------	01.8144
12	27.588	00.431	Traces.	------	------	13.792
13	21.780	01.70	10.88	15.827	0.0204	05.44
14	02.904	Traces.	03.262	------	------	00.810
15	------	00.8715	03.407	01.9068	------	------
16	03.176	09.639	04.536	06.804	0.025	01.4175
17	14.520	02.268	Traces.	Traces.	------	05.6725
18	05.808	09.075	18.15	Traces.	------	------
19	09.5832	Traces.	05.850	03.745	------	------
20	04.356	10.88	03.944	02.176	------	------
21	10.164	15.90	04.293	Traces.	------	02.26
22	02.9765	Traces.	01.488	01.395	0.02232	01.674
23	04.352	04.764	01.4231	00.3045	0.109354	------
24	04.352	01.588	04.7936	00.2247	0.3206	00.265
25	03.630	00.5675	08.1868	10.89	0.124	00.6010
26	08.712	03.176	53.928	02.996	0.1378	00.265
27	03.811	03.176	30.464	06.664	0.07072	00.0414
28	04.352	03.176	02.996	04.794	0.0509	00.532
29	14.6125	------	11.344	11.344	------	02.014
30	------	165.376	18.1250	16.66	------	00.242
31	01.452	29.040	------	------	0.06807	00.242
32	11.616	------	54.45	05.808	------	00.322
33	11.616	01.815	94.380	04.45	------	00.633
34	07.260	------	126.080	18.144	------	00.403
35	07.260	01.134	36.288	15.4224	------	00.403
36	01.452	02.27	20.421	11.118	------	00.1611
37	14.520	02.268	62.370	Traces.	------	00.403
38	05.898	03.630	32.670	Traces.	------	00.322
39	11.616	06.3525	58.080	02.359	------	00.645
40	------	------	------	Traces.	------	------
41	03.630	90.72	------	------	------	00.607
42	10.8896	1.70	13.60	Traces.	------	00.604
43	01.161	0.363	17.756	Traces.	------	00.065

INTERPOLATION OF RAINFALL BY THE METHOD OF CORRELATION [1]

By C. E. GRUNSKY

It was in 1885 that it fell to me, as assistant State engineer, to prepare a rainfall map of this State. Records were available at 200 or more stations. It was found that at a large number of these stations observations had commenced in 1871 and that for this group of stations the records, covering 14 years and kept under the supervision of railroad employees, were fairly good. There were only a few widely scattered places in the State at which rainfall records extended back over more than 30 years. It was, therefore, determined to ascertain from each available record the average annual rainfall for this 14-year period and to let the isohyetal lines on the map represent the average rainfall at any point for this period.

[1] The article by Eric R. Miller under the above title, published in this REVIEW, 59: 35, has elicited the account herewith of a method of interpolation followed many years ago in California by Mr. C. E. Grunsky, of C. E. Grunsky Co., engineers, 57 Post Street, San Francisco, Calif. Mr. Grunsky's letter is given above.—*Ed.*

When at any station there was no record for some individual month, recourse was had to the records at near-by stations to approximate the lacking figures. For each such near-by control station the relation of the particular month's rainfall to that of the station's average annual rainfall was then ascertained. The 14-year period only was taken into account in estimating this relation. According to proximity or to similarity of topographic and orographic features, the several approximations thus obtained always expressed in per cent of normal annual rain (in this case the 14-year average), were weighted and were then used to establish the missing record expressed in percentage of the annual normal. This percentage applied to the station normal thereupon determined the desired amount in inches.

At some stations the record covered only a part of the 14-year period. In each such case the incomplete record was compared with the records for corresponding periods at such near-by stations as had complete records. The relation established by this comparison was accepted as the relation between the normal rain at the particular station in question and the normal rain at the control station. If several control stations were brought into consideration the several individual results were weighted, as explained, not by methods of least squares, but according to personal judgment, and the result was accepted with confidence.

It is to be noted, however, that the relation between the amounts of rain at near-by stations is much more likely to be fairly constant in California where the rain producing cyclones are generally of vast extent than would be expected where much rain falls during storms which cover only small areas.

Any refinement of calculation to give better results than can be obtained by the foregoing simple method is never warranted. This will appear when it is considered that the best that can be done is to secure an approximation. The records of the past are, moreover, generally required to serve only as a basis for a prediction of what may be expected to happen in the future. There is, furthermore, always so much uncertainty in the premises that no intricacy of calculation can give any more dependable results than the simple comparison above described.

TESTS OF RAINFALL-INTERPOLATION METHODS

ERIC R. MILLER

[Weather Bureau, Madison, Wis.]

The results of applying to some difficult cases the method of interpolation of rainfall data recommended in the MONTHLY WEATHER REVIEW, January, 1931, may be of interest to meteorologists on account of the light thrown on some unusual rainfall phenomena.

Figure 1 is a scatter diagram showing the correlation of the monthly rainfall in June for 33 years between 1895 and 1930 at Center Hall and State College, Pa., about 10 miles apart. The correlation coefficient for all cases is 0.52; excluding the cases of 1909, 1922, 1930, it is 0.84. Examination of the records shows that local downpours occurred at one or other of the stations in the excluded cases.

A similar diagram for June rainfall, 34 years between 1888 and 1930, for Titusville and Merritts Island, Fla., 17 miles apart, Figure 2, shows that the incoherence that affected only 3 of the 33 cases in Pennsylvania has here spread to the whole group. In spite of this, the wider range of values gives a higher coefficient, 0.61.

A third type of correlation, close for small values, dispersed for large, is shown in Figure 3, January rainfall, 20 years, 1897–1916, Campbell and Boulder Creek, Calif. About 15 miles apart, chosen on account of the large difference in their average January rainfalls, 4.07 and 14.65 inches, respectively.

Mr. C. E. Grunsky, the well-known engineer, has suggested comparison of the regression method of estimating

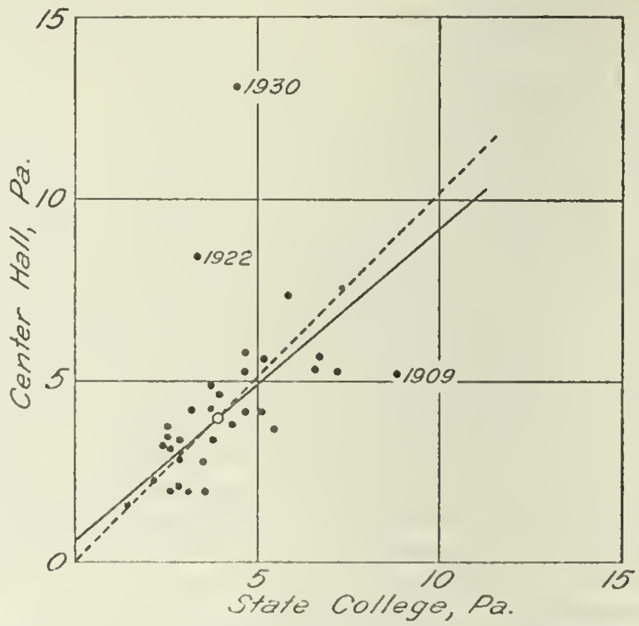


FIGURE 1.—Scatter diagram showing correlation of monthly total rainfall for June for 33 years

rainfalls with a method that he devised in 1885 when, as assistant State engineer of California, it devolved upon him to prepare a rainfall map of the State. The basis of his method is the assumption that the ratio of rainfalls

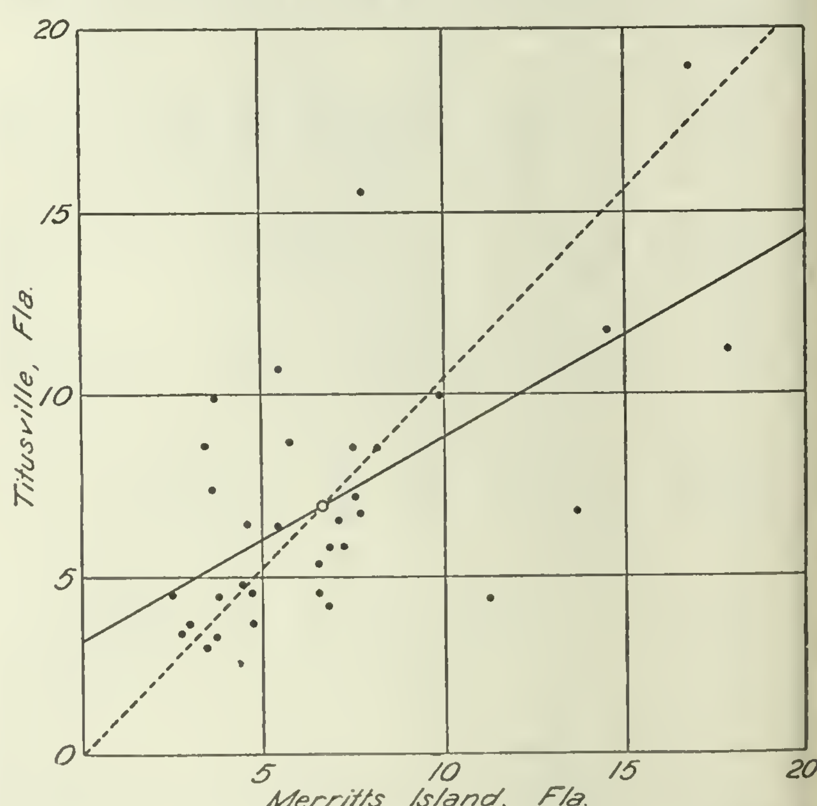


FIGURE 2.—Scatter diagram showing correlation of monthly total precipitation for June, 34 years

at neighboring stations is always the same as the ratio of the normals.

The regression equations minimize the sums of the squares of the deviations of the observed rainfalls from the computed. A suitable test of Mr. Grunsky's method consists in comparing the deviations of computed from observed rainfalls by the two methods.

The regression equations shown in the figures as continuous lines are:

$y=0.84\times 0.54$ Center Hall on State College (1909, 1922, 1930 excluded).
$y=0.57\times 3.03$ Titusville on Merritts Island.
$y=3.11\times 1.99$ Boulder Creek on Campbell.

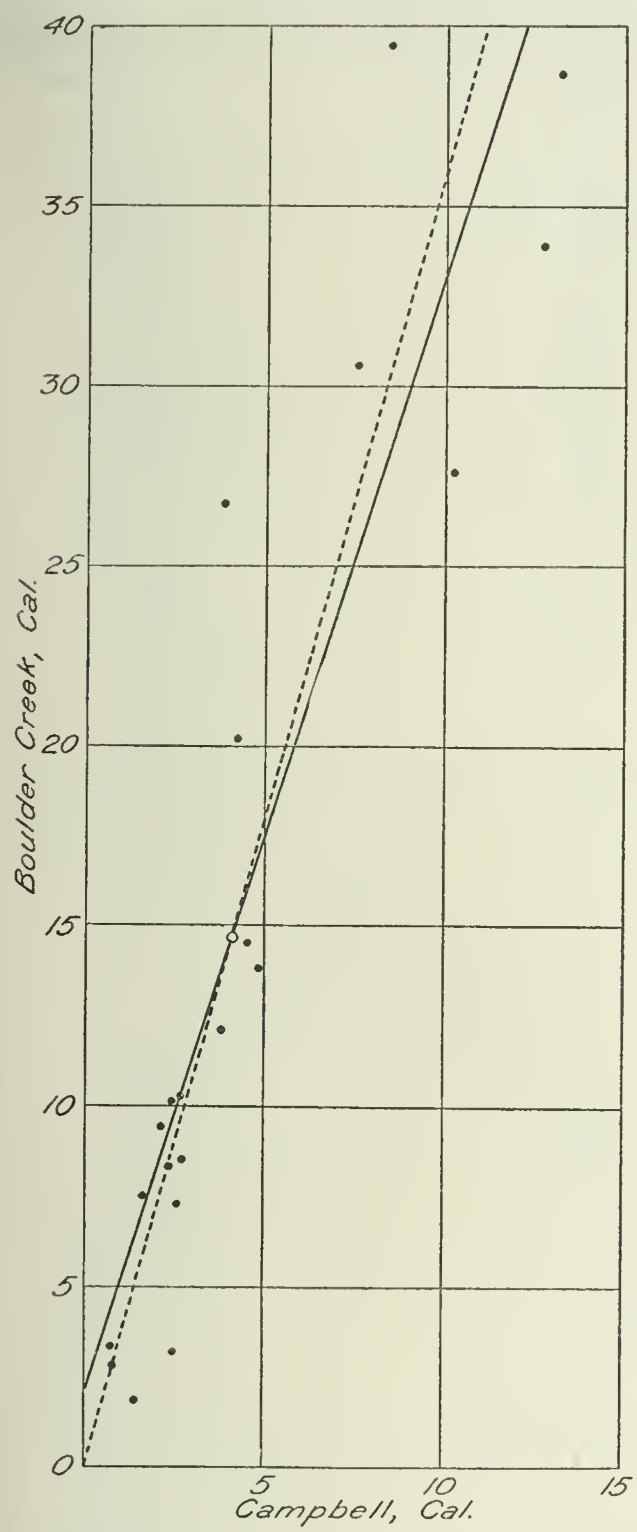


FIGURE 3.—Correlation of January rainfall, 20 years

where the amounts are in inches of rain per month.

The equations representing Mr. Grunsky's method are:

$$y=0.995\times$$
$$y=1.015\times$$
$$y=3.60\times$$

and these appear on the diagrams as dotted lines.

The results of the comparison are as follows:

	Sum of squares of deviations	Standard deviation	Probable error	Mean deviation	Maximum deviation
Center Hall:					
Regression	22.3470	0.86	0.59	0.75	1.85
Normals	29.0337	.97	.67	.77	1.88
Difference	6.6867	.11	.08	.02	.03
Titusville:					
Regression	316.3134	3.05	2.08	2.17	8.14
Normals	329.1524	3.11	2.13	2.39	7.79
Difference	12.8390	.06	.05	.22	−.35
Boulder Creek:					
Regression	527.7698	5.14	3.55	3.80	12.53
Normals	577.5369	5.37	3.72	3.91	12.60
Difference	49.7671	.23	.17	.11	.07

These results indicate that Mr. Grunsky's method is satisfactory for practical purposes, with the advantage of eliminating a great deal of arithmetical work. The normals should be based on simultaneous data.

The preparation of a scatter diagram is not very laborious, and affords valuable information about the closeness of correlation.

HIGH FLIGHTS OF SOUNDING BALLOONS [1]

By E. FRANKENBERGER

[Deutsche Seewarte Hamburg]

The author expresses the fact that most of our knowledge of the composition of the stratosphere is gained by indirect methods, and that it would be valuable if air-soundings, with direct measurements, were made to heights of over 30 km.

In the spring of 1929 the meteorological experimental bureau of the Deutsche Seewarte undertook to solve the problem of getting measurements at high altitudes by systematic sounding balloon flights. Mathematical calculations of the forces of expansion in partially elastic balloons were made, and by research the elastic qualities of balloon rubber and the most favorable amount of gas for sounding balloons were determined. As a result, a sounding balloon on November 2, 1929, reached a height of 35 km.

The question of the dependence of thermometer lag on the rate of ascent is taken up and also the problem of ventilation. The author says that the condition for attaining the greatest altitude is that the balloon rise until is reaches its floating level and then burst. To accomplish this it is stated, they must be inflated so that they rise slowly in the lower levels and that this slow vertical motion (180 to 240 m. per minute) gives poor ventilation. Thus the true temperatures must be calculated from the indicated temperatures by the use of thermometer lag factors. Investigations into the dependence of thermometer lag on air densities and ventilation are in progress for the tropospheric air densities and are under consideration for the small air densities of the stratosphere.

Five balloons 2,500 mm. (98 inches) in diameter were specially prepared for high flights during the international

[1] Analen der Hydrographie und Maritimen Mwteorologie, Jan., 1931, pp. 20–22.

month of September, 1930. The days with high flights were the 8th, 13th, 14th, 24th, and 25th.

Computation of the record of September 8 gave a maximum altitude of 35.9 km. A small Bosch instrument was used and due to the multiple adjustments of the pressure element, a deflection of a few tenths of a millimeter of the pressure pen would produce an error ±3 km. in the maximum altitude. Calculating the height only from the hydrogen filling, the size of the balloon, and from the bursting point and elasticity of the balloon rubber, a maximum altitude of 33 km. is obtained. Also, in favor of the maximum altitude of 33 km. is the fact that with it the rate of ascent in the upper levels is constant, while a maximum altitude of 35.9 km. gives an improbable increase in rate of ascent in the highest level.

On September 13 the balloon was equipped with a large Bosch instrument. For this instrument the maximum altitude of 26.5 km. is probably not more than ±0.5 km. in error. This balloon burst prematurely, due possibly to strain caused by the greater weight of the instrument.

September 14 another small instrument was sent up. It entered a cold current at 24 km. and the balloon stopped rising for a time, then went up again and burst at 32.5 km. The pressures and temperatures of the higher layers were obtained from the descent record.

The ascents on the last two days did not reach the desired heights.

The nine flights in September, 1930, reached a mean maximum altitude of 23 km. It is possible to reach altitudes of over 30 km. only with great care and considerable expense.

The results of these high flights together with the higher Hamburg flights from 1926 to 1930 are to be published soon. These results show that an increase of temperature at heights over 30 km. can not be firmly established. The three highest flights of September, 1930, show minimum temperatures of about −55° C. at about 12.5 km. and temperatures approximately 8° higher at the maximum altitudes. This might be partly due to insufficient ventilation and radiation effect.

The results of the September flights indicate that for further work, investigation should be made into air density and ventilation effects on temperature measurements and the following problems are to be solved: (1) Improvement of the pressure measurements; (2) improving the quality of rubber; (3) development of a connecting apparatus whereby the weight of the instrument is distributed evenly over the balloon.—*Translated and abstracted by J. C. Ballard, U. S. Weather Bureau.*

AGREEMENT FOUND IN RECORDS OF FERGUSSON SOUNDING-BALLOON METEOROGRAPHS

By L. T. SAMUELS

[Weather Bureau, Washington]

During the series of sounding-balloon observations made at Royal Center, Ind., during February, 1931 (international month), two meteorographs were attached to the same balloon in a few instances in order to determine the agreement between the individual records. Also, on a few days sounding balloons were released shortly before and shortly after sunset in order to determine any possible effects of insolation on the meteorograph.

In Figure 1 are shown the temperature-altitude graphs of an observation made February 7 when two meteorographs were attached to the same balloon. Meteorograph No. 693 was hung about 80 feet below the balloon and No. 679, about 15 feet lower. The ascensional rate averaged 215 meters per minute up to 9 km. and 187 meters per minute to the highest altitude reached, viz. 17 km. Each of the records was computed independently and an inspection of the graphs (fig. 1) shows very close

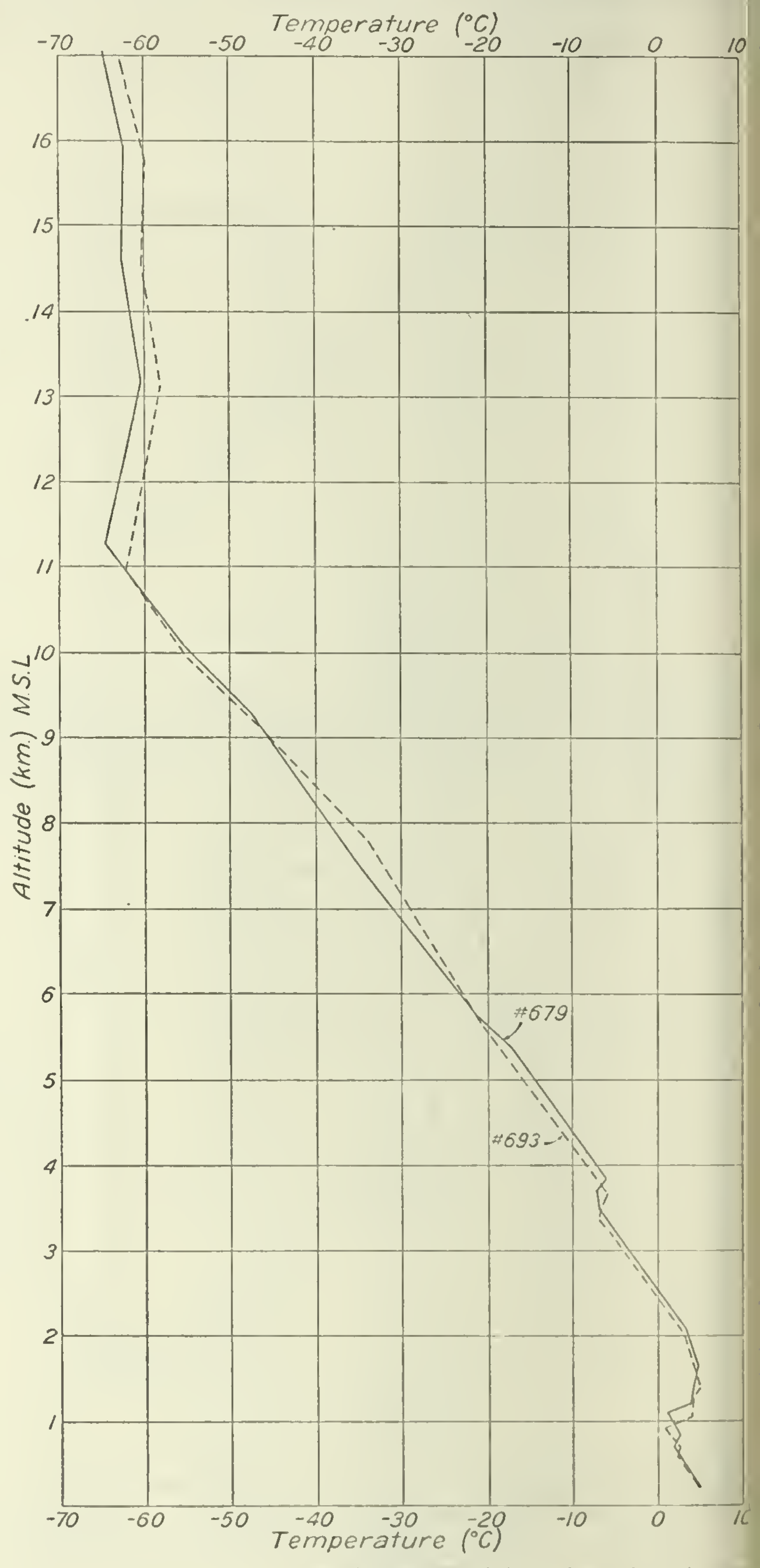


FIGURE 1.—Temperature-altitude graph of sounding-balloon observation using two meteorographs

agreement. It will be noted that at no point does the temperature recorded by both instruments differ by more than 3° C. Two marked inversion layers are shown between 1 and 2 km. and between 3 and 4 km., respectively. The height of the base of the stratosphere agrees to within 300 meters, or 3 per cent. The variations in lapse rate in the stratosphere are in striking agreement

The relative humidities are likewise found to be in very close agreement. The greatest difference at any particular level was 10 per cent, while in most cases the difference was considerably less.

The general agreement found in the other cases where two instruments were attached to the same balloon was of the same order as that shown in Figure 1.

Figure 2 shows the temperature-altitude graphs of two observations made on February 2, with an interval of

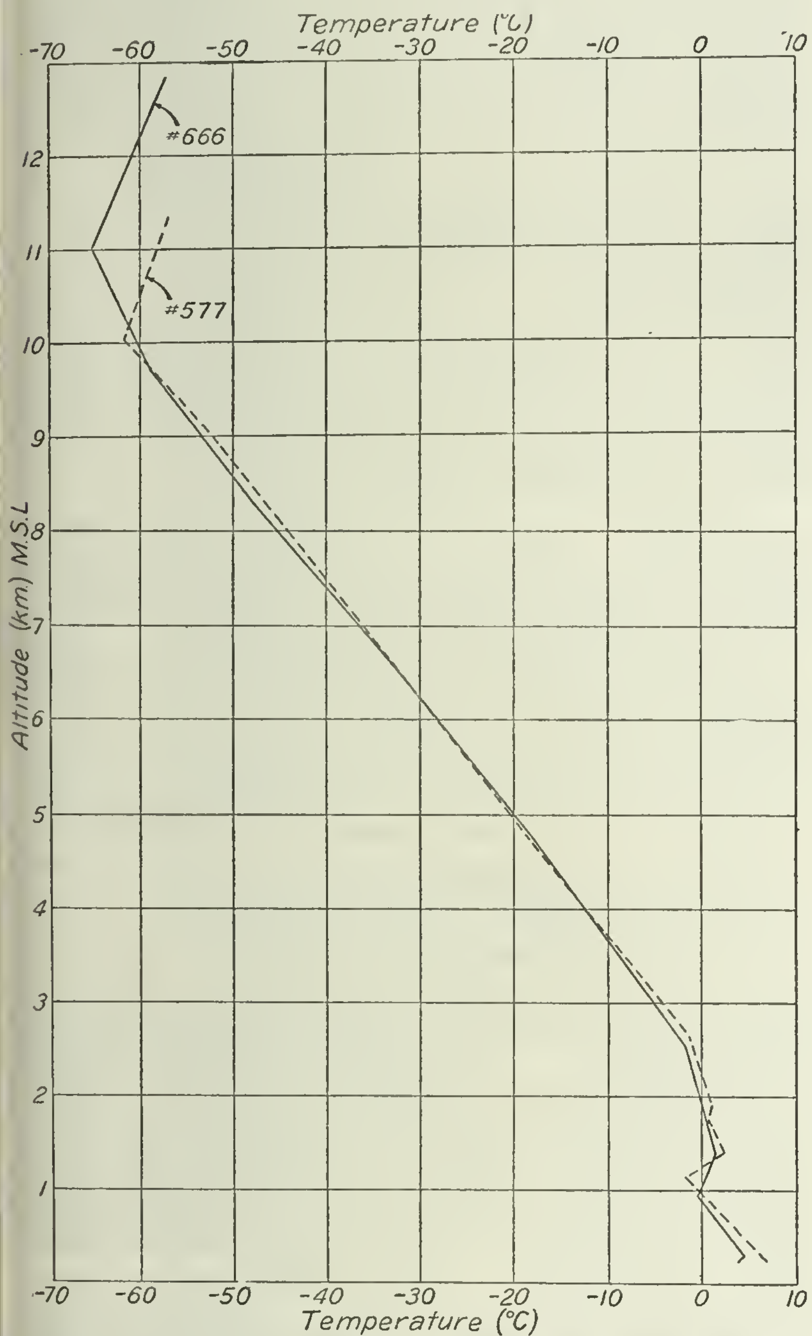


FIGURE 2.—Temperature-altitude graph of two sounding-balloon observations made 1 hour 23 minutes apart

1 hour and 23 minutes between them. The first balloon carrying meteorograph No. 577 was released at 3:55 p. m. (C. S. T.) (69 minutes before sunset), and the second balloon with meteorograph No. 666 at 5:18 p. m., or 14 minutes after sunset.

The agreement between the two graphs, it will be seen, is strikingly close up to the base of the stratosphere. The latter is found to be 1 km. higher at the time of the second observation. At least a part of this difference can be attributed to an actual change in atmospheric conditions since the descent portion of the record of the first observation indicated the stratosphere to be about 200 meters higher than on the ascent. A rise in the stratosphere would be expected from the fact that a high pressure area was moving in rapidly over Royal Center at the time.

It is evident that no vitiating effects from insolation resulted.

WHY THE READINGS OF THE MERCURIAL BAROMETER ARE CORRECTED FOR BOTH TEMPERATURE AND LATITUDE AND THE READINGS OF THE ANEROID BAROMETER LEFT UNCHANGED

By W. J. HUMPHREYS

[Weather Bureau, Washington]

It is an old story, of course, why we correct the readings of the mercurial barometer for both temperature and latitude and those of the aneroid for neither. Nevertheless, it may be worth telling again, since there is no convenient literature to which one can refer for an answer to this frequent question.

The aneroid barometer, a vacuum chamber with a flexible top attached to a movable index, responds only to changes in pressure, because the elastic reaction of its inclosed compressed spring that keeps the top from collapsing is practically independent of temperature, within the range of ordinary weather, and wholly independent of gravity. The *pressure* reading of the aneroid therefore needs no correction, save only that which might be necessary to make it agree with that of a standard instrument under the same conditions.

The mercurial barometer, on the other hand, a vertical glass tube sealed at the top, partly filled with mercury (vacuum above) and its open lower end dipping into a basin of mercury exposed to the air, balances, not the pressure of one fluid against a standard spring, as does the aneroid, but the pressures of two fluids against each other where they come together—in this case the pressure of the mercury against that of the air at their interface in the basin. Now, the pressure exerted by the mercury obviously increases directly with the vertical distance between its two surfaces; that is, with the "height" of the barometer, with the density of the mercury, and with the gravity pull per unit mass. But the density of the mercury varies with its temperature and the gravity pull with both latitude and height above sea level. Hence to find the *actual pressure* of the air from the current height of the barometer it is necessary to alter the reading to what it would be at some standard temperature (in addition to the similar correction for scale expansion) and standard gravity.

Why, though, this special interest in the pressure of the air rather than the mass of it overhead, for instance? Because the thing that makes the winds to blow, and thus effects weather transportation, is not primarily inequalities in the mass distribution of the air, but differences between the atmospheric pressures of neighboring places at the same level. This is why we commonly want the readings of our barometers to be in terms of actual pressures, or their equivalents, and that is why ordinarily the readings of the mercurial barometer are corrected for temperature and for latitude (gravity) and why the readings of the aneroid are left unchanged.

If, however, one had occasion to measure, or compare, the masses of air overhead at different places, as he might in the study of solar radiation, he would need to correct the readings of the aneroid barometer for latitude (gravity) and not the readings of the mercurial barometer.

A COMMON HUMIDITY ERROR

By W. J. HUMPHREYS

[Weather Bureau, Washington]

Many people who should know better seem to have surprisingly vague if not even confused ideas about humidity, and where there is much smoke there generally is some fire. Those who have to do with the measurement of humidity would insist, if questioned, that they know perfectly well what the terms "absolute humidity" and "relative humidity" properly mean. Perhaps they do; nevertheless many, if they should condescend to answer at all, would say, in substance, that absolute humidity is the mass of water vapor present per unit volume of the air, and relative humidity the ratio of the amount of water vapor present to the amount necessary to saturate the air at the same temperature.

That sounds familiar and orthodox, but it reveals confusion at best, for the air has nothing to do with either absolute humidity, properly defined as the mass of water vapor per unit volume (of space, not air), or relative humidity—the ratio of the mass of water vapor present per unit volume (of space) to that which would saturate a unit volume at the same temperature. Be certain not to add "and same pressure," which we sometimes hear, for that refers to the atmosphere, which, as just stated, has nothing to do with the phenomenon in question.

There is, however, one very useful humidity concept that does involve the air, namely, the mass of water vapor per unit mass of humid air. This is called "specific humidity."

But entirely apart from definitions we often see and hear expressions about the air taking up water vapor and about the great avidity of warm air for water vapor. Now, as a matter of fact, the air does not "take up" water vapor—it is not a sponge; and warm air has no avidity, chemical or other kind, for water vapor. All the air does in this connection is to slow down the rate of evaporation and diffusion. It is not the air but the space, air or no air substantially alike (a shade better without the air), that has the vapor capacity. Neither is it the temperature of the air but the temperature of the vapor (again air or no air) that determines the amount of water vapor per unit volume necessary to produce saturation.

Most of us say the air takes up water vapor. Let us forget it, if we can, and say space instead, as that is what we mean, if we understand the phenomenon aright.

TEMPERATURES IN THE HIGHER LAYERS OF THE STRATOSPHERE OVER LINDENBERG

By J. REGER

[Published in Beiträge zur Physik der freien Atmosphäre, XVII Band, Heft 2, pages 176–178. Translated and abstracted by J. C. Ballard, Aerological Division, Weather Bureau, Washington, D. C.]

In making this study of temperatures in the stratosphere the author has chosen a total of 123 sounding-balloon flights, 81 of which were made in the last four years and the remainder in earlier years. No flights in which the clock stopped prematurely, or which failed to reach a height of at least 17 kilometers, were used in the study, and since temperatures in only the upper levels were to be considered, the 14-kilometer altitude was chosen as the starting point.

Two tables of observed data were compiled and summarized. Some of the more interesting points brought out are as follows:

(1) The yearly means indicate an almost constant temperature from 14 to 16 kilometers and thereafter a slow increase, the mean values at 20 kilometers being 1.43° C. higher than at 14 kilometers.

(2) In winter there appears to be a mean decrease of 2.57° C. from 14 to 20 kilometers.

(3) In summer the mean values indicate the temperature at 20 kilometers to be 4.27° C. higher than at 14 kilometers.

(4) The means of seven flights made in summer and autumn near or after sunset give temperatures at 20 kilometers 1.04° C. lower than those at 14 kilometers.

(5) The means of 10 summer flights made near midday show an increase of 5.01° C. from 14 to 20 kilometers.

Points (2) and (3) would seem to indicate a seasonal variation in temperature between 14 and 20 kilometers. However, the author brings out the fact that the starting time for the greater part of the flights was about 8 a. m., and since there is considerable seasonal difference in the altitude of the sun at this time, the increase may be due to insolation effect. He thinks this theory is supported by points (4) and (5), which indicate a diurnal variation of about 6° C. between noon and evening at 20 kilometers, while the mean temperatures at 14 kilometers differed very little. It is his opinion that there is probably no diurnal variation at 20 kilometers and that therefore most of the increase in temperature from 14 to 20 kilometers must be due to insolation effect.

Therefore, the conclusion is reached that sounding-balloon flights should be made during a lower sun if possible. If this were done, reliable observational data would eventually be collected for great heights where the ventilation, measured in terms of air density × vertical speed of ascent, is small. It is obviously important that the insolation effect be negligible where the ventilation is poor.

Remarks by abstracter.—The investigation of ventilation and insolation effects on indicated temperatures in the higher levels is very important, as all temperature records in the stratosphere are open to question when considered in this light. In the determination of ventilation effect on the temperature element the importance of testing under reduced pressure should not be overlooked, since the ventilation at small air densities must be poor even with a rate of ascent which would be favorable in the lower levels. If it is found impracticable or impossible to maintain sufficient ventilation in the upper levels by increasing the rate of ascent, it may be necessary to make all sounding-balloon flights after sunset, as suggested by Mr. Reger. Even under these circumstances it may be found necessary to compute by an empirical formula the true temperature from the indicated temperature, rate of ascent, and air density.—*J. C. Ballard.*

RUBENSTEIN'S CLIMATIC ATLAS OF THE U. S. S. R.

Reviewed by C. F. BROOKS

The temperature section, Part I, Section I, of Eugenie Rubinstein's atlas of the climate of U. S. S. R.,[1] includes detailed monthly and annual maps of sea-level temperatures; mean annual range; the progress of the mean isotherms of −5°, 0°, 5°, 10°, and 15° C. in spring and fall by 10-day intervals; the number of days in the year with daily mean temperature over −5°, 0°, 5°, 10°, 15°; differences of the successive monthly means of temperature; and two plates including graphs of the monthly course of temperature at 28 stations.

[1] Eugenie Rubinstein, Klima der Union der Sozialistischen Sowjet-Republiken Teil I. Die Lufttemperatur. Lieferung I. Monatsmittel der Lufttemperatur im Europäischen Teil der U. S. S. R., Geophysikalisches Zentral-Observatorium, Leningrad, 1927, 45 maps and diagrams, 40 by 52 cm.

The sea-level temperature maps show strikingly the gradients in temperature along the coasts, which in winter are particularly steep along the Murman coast and the northeastern shore of the Black Sea. In spring the contrasts in the south are much diminished, but in the northeast they are very great indeed, amounting in April to 12° C. in 7½° of latitude, or 1.6° C. (2.9° F.) per latitude degree. The summer months show striking contrast (about 6° C. difference in July) between the chilly Arctic coast and the northern tundra. The larger lakes show a 2° or 3° C. excess of temperature relative to land in autumn and an equal deficiency in early summer. The annual range is under 20° on the western Arctic coasts, but 27° to 30° only 50 miles from the northern shore. In eastern and southeastern Russia the range is 34° to 39° C.

The advance of spring and fall as shown by the five isothermal maps for different temperatures indicate strikingly how spring bursts upon the plains of central Russia and how suddenly winter sets in. In central Russia the −5°, 0°, 5°, and 10° isotherms advance 400 to 700 miles in 10 days in spring, but not quite so fast in fall. In the north, however, the advance is slowed to 100 miles in 10 days. Correspondingly, the changes in temperature from month to month reach large values in spring and fall, mostly 7° to 11° for April to May and 6° to 9° for September to October.

The maps of frequencies of days above certain temperatures indicate great differences, especially in the number of days over 15° C., which might be called mild days. These range from 150 in the Crimea to 100 about latitude 52°, 50 at latitude 61°, and 0 at latitude 65°.

The maps are clearly presented, being black lines on a light brown hachured base, with blue for water (two shades, for shallow and deep). The scale is ample and the isothermal interval, 1° C., small enough for all required detail.

THE DRY SEASON OF THE PANAMA CANAL

By R. Z. Kirkpatrick, *Chief of Surveys*

[Balboa Heights, C. Z., May 25, 1931]

1. The drawing on the opposite page is historical of the beginning and ending of the Canal Zone's dry seasons since American occupation.

2. It will be noted that there are considerable variations; but an approximate average is: Beginning January 1, ending May 5; length, 4 months 5 days.

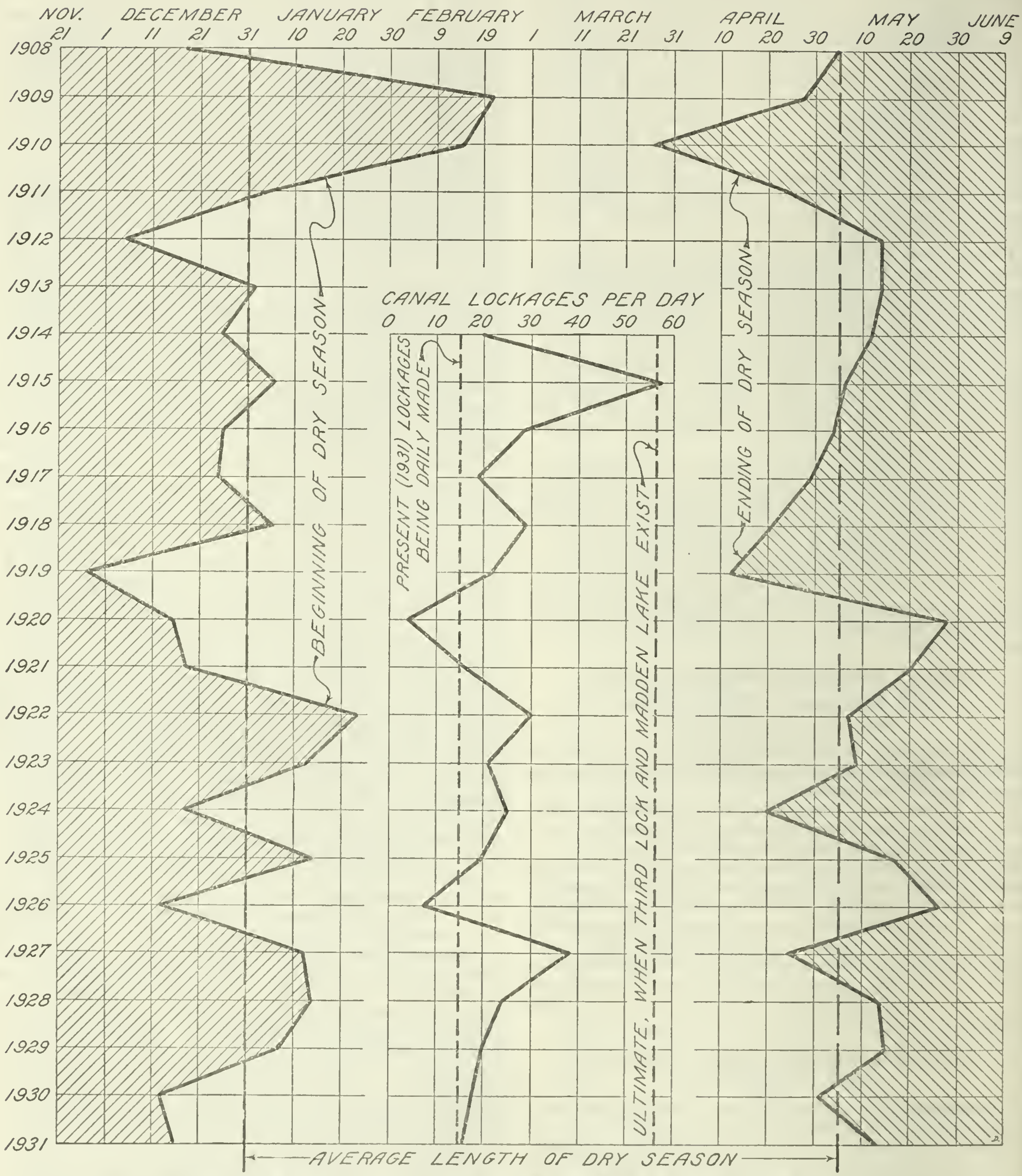
3. The inset curve indicates the number of lockages Gatun Lake's available storage would have provided, after allotting 1,700 c. f. s. for making hydroelectric power, during each year since the canal began operation in 1914. It is evident that the Madden Dam and Reservoir (happily under construction) will be needed to tide over very dry seasons, and that the contemplated new locks and storage reservoir will take care of traffic needs until many decades from now.

THE CLEVELAND, OHIO, STORM, JUNE 26, 1931

By G. Harold Noyes

A violent storm, with resulting heavy damage, occurred during midday in Cleveland on June 26, 1931.

Distant mutterings of thunder had been heard during the preceding night beyond the Lake Erie horizon, with lightning showing behind the peaks of distant cumuli. The 8 a. m. observation of the 26th did not show any notably unusual conditions, other than its being oppressively warm, with temperature of 80° and relative humidity of 74 per cent. With the rising of the sun, temperatures moved upward to correspond, and the wind shifted from west to southward at 7:55 a. m. Later developments, however, led to the conclusion that even before 8 o'clock a great convectional disturbance was accumulating over Lake Erie to the west-northwestward of Cleveland. Cloud cover increased very rapidly, commencing at 8 o'clock; the sun was obscured at 8:04 a. m., and a gentle shower began at 8:29 a. m., the wind at that time shifting from southwest through west for 3 minutes, into northwest for 12 minutes, thence into north for 20 minutes, northeast for 30 minutes, then east for 22 minutes, then back to north for 6 minutes; the winds were a little gusty, but not rising above 18 miles per hour. Meantime the gentle shower continued, and temperature dropped from 80° to 71°. The barogram showed a slight notch, down and up, immediately after 8 o'clock. Distant thunder was heard at intervals from 7 a. m. on. Between 9 and 10 a. m. the activity of the lower clouds was confused, but highly significant of later developments. Detailed movements in four levels were observed, reading down: From west-northwest and west, north, and at lowest level varying rapidly from northeast, east, and east-southeast. At 10:36 a. m. gentle rain suddenly became excessive, amounting to 0.28 inch in about 5½ minutes, with wind remaining under 12 miles per hour. This rainfall catch was excellent. At 11 a. m. rain again reached a rapid but not excessive rate, with wind not rising above 15 miles per hour, mostly from the southeast. From 10 a. m. to 1 p. m. the barometer showed marked activity; from 10:10 to 10:20 there was a quick fall and rise; from 11 to 11:30 it fell 0.06 inch, then commenced rising, and rose about 0.15 inch by 1 o'clock. During this period the brunt of the storm swept over the city from the lake. At 11:49 a.m. the storm broke, the wind rose from 8 to 12 miles per hour in less than a minute to 56, with an extreme of 64 at 11:52, and rain commencing at excessive rate and continuing to 12:10 p. m., and the wind continuing above 45 to 12:15, the rain catch, therefore, at this period was considerably deficient, but was recorded as 0.41 in 15 minutes. The wind, rain, and ligthning during this period, immediately before and after noon, did severe damage. Lightning struck in many places; two men were killed outright and buildings damaged, and several electric circuits were burned out. The wind blasted shrubbery and foliage, uprooted trees, and broke off limbs, so that damage of this sort was widespread throughout the city, and thence to the eastward into the next county. The rainfall was at such rate that watercourses, both natural and those recently constructed, were inadequate to carry the run-off. In nearly all down-town localities there was little or no flooding, but in eastern parts of the city and suburbs underpasses were flooded, stopping traffic, cellars filled, culverts were washed out, and road surfaces and curbs undermined. Some insecure buildings were razed by the wind, and many plate-glass windows on the south side of Public Square were blown in. Windows in many scattered sections were broken, and this was followed by rain damage. Hail fell from 10:36 to 10:39 a. m., the pellets being up to three-eighths inch in diameter; the hail was unimportant and any damage therefrom was obliterated by the more serious damage a short time later. The pellets were flattened, showing concentric layers, finely traced. Precipitation from hail was probably not over a trace. The margins of the storm reached into central portions of the State, with greatly weakened energy, and as its maximum focus advanced eastward, or east-southeastward, into Pennsylvania it rapidly diminished in force. It was felt only slightly at Erie, Pa., and



Graphical presentation of beginning and ending of dry season at Panama Canal, 1908–1931, and other data
The extent of dryness is expressed in canal lockages per day, 1914–1931, inclusive. Note: It is assumed that one lockage per day requires 70 c. f. s., that Gatun hydroelectric leakage and municipal water requires 1,700 c. f. s., and that Gatun Lake's storage between elevations 87 and 81 feet is used

little, if any, at Buffalo, N. Y. The western margins of the storm were near Sandusky, without damage.

Storm-sewer construction and catch basins in the areas immediately near Public Square appeared to be adequate for the run-off of this storm, but in the highlands and eastern suburbs, either the recent construction of water-courses and their resultant constriction is woefully under-sized, or else the rain in that region was much greater than down town.

The loss, according to newspaper headlines, was in the millions.

A TORNADO IN NEW MEXICO[1]

By C. E. LINNEY

[Weather Bureau Office, Santa Fe, N. Mex.]

Just about a year after a destructive tornado struck Wagon Mound, Mora County, N. Mex., a second tornadic storm was observed to form on June 5, 1931, near the small village of French, Colfax County, about 35 miles northeast of Wagon Mound. This second tornado moved slowly east-southeast through a thinly settled country, doing but relatively little damage by reason of the sparsely settled country. It passed into and across Union County, doing quite a bit of damage to buildings and causing the death of a 3-year-old girl by an out-building crashing upon her. The property loss in the Gladstone district is estimated at about $1,500 and in the Barney and Sedan districts about $10,000 and $20,000, respectively.

The tornado was under observation during its entire course of about 90 miles. It dissipated after crossing the Texas border.

[1] Condensed from the original.—*Ed.*

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING JUNE, 1931

By HERBERT H. KIMBALL, In Charge Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged above the normal intensities for June at Washington and below the June normals at Madison and Lincoln.

Table 2 shows an excess in the total radiation received on a horizontal surface as compared with the normal amount for June at Washington and New York; close to normal at Lincoln, Gainesville, and La Jolla; and a deficiency at all other stations for which normals have been computed.

TABLE 1.—*Solar radiation intensities during June, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
Washington, D. C.											
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 2	6.50				1.06	1.42					7.29
June 3	9.47					1.17	0.80				7.29
June 4	10.59			0.68	0.92	1.19					11.38
June 9	8.81		0.69	0.82	1.00						9.14
June 12	11.81				0.99						11.81
June 17	9.83		0.70	0.95	1.15	1.28					8.18
June 18	10.59		0.69	0.84	1.02	1.24					8.48
June 19	13.13		0.62	0.74	0.95	1.26	0.94				16.79
June 20	16.20			0.85	0.94	1.19					14.60
June 25	14.10					1.26					10.97
June 29	10.59		0.74	0.96	1.12	1.32	1.04				9.83
June 30	13.61			0.90	1.10	1.29					13.61
Means			0.69	0.84	1.02	1.26	0.93				
Departures			+0.03	+0.07	+0.09	+0.03	+0.02				
Madison, Wis.											
June 8	6.76	0.81	0.87	0.99	1.17	1.30					6.02
June 16	9.47				1.15						10.97
June 18	11.38					1.24					17.37
June 24	14.10					1.19					19.89
June 25	18.59			0.81	1.00	1.20					20.57
June 26	18.59					1.22					20.57
June 27	19.23					1.17					19.23
June 29	19.89	0.48	0.57	0.73	0.91	1.18					18.59
June 30	17.96		0.61	0.75	0.88	1.19					16.20
Means		(0.64)	0.68	0.82	1.02	1.21					
Departures		−0.01	−0.16	−0.13	−0.08	−0.11					
Lincoln, Nebr.											
June 3	12.68						1.11	0.93	0.71		11.81
June 8	10.59		0.59	0.73	0.90	1.19					12.68
June 16	15.11				0.96		0.98	0.78			13.13
June 17	15.65		0.59	0.73	0.95	1.21	1.06	0.89	0.69		15.65
June 18	16.79		0.80	0.93	1.04	1.21	1.02	0.78			16.20
June 23	14.10						1.06	0.89	0.76		16.20
June 24	15.11				1.13	1.30					15.11
June 25	16.20				1.09	1.35					15.11
June 26	16.20		0.78	0.92	1.11	1.32	1.03	0.86	0.73		15.11
June 27	17.37					1.29	1.01	0.82	0.69		14.10
June 29	16.79		0.64	0.78	1.00	1.25					15.65
June 30	15.65		0.78	0.91	1.09	1.34					14.10
Means			0.70	0.83	1.03	1.27	1.04	0.85	9.72		
Departures			−0.06	−0.09	−0.06	−0.07	−0.05	−0.05	−0.07		

[1] Extrapolated.

Skylight polarization measurements obtained on five days at Madison give a mean of 54 per cent, with a maximum of 61 per cent on the 8th. At Washington, measurements obtained on three days give a mean of 59 per cent, with a maximum of 64 per cent on the 4th. These are above the corresponding June averages for Washington. At Madison the values are slightly below the corresponding averages.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
AVERAGE DAILY TOTALS												
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
June 4	501	391	463	294	333	626	411	[1] 606	600	389	655	510
June 11	475	539	559	423	371	659	500	457	707	422	532	384
June 18	574	467	605	442	480	626	495	506	693	462	556	244
June 25	630	582	618	440	509	716	394	453	761	466	654	283
DEPARTURES FROM WEEKLY NORMALS												
June 4	+17	−118	−66	−116	−65	−8	−38	+40	−82	−36		
June 11	−24	+42	+20	+17	−29	−2	+13	−43	+11	+14		
June 18	+89	−52	+41	+28	+70	−75	+2	+37	−26	+17		
June 25	+166	+41	+29	+9	+90	+15	−92	−38	+35	−9		
Excess or deficiency since first of year on July 1, 1931	+1,461	−4,291	+434	−1,323	−217	+554	−1,128	−534	−315	−2,674		

[1] 5-day mean.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups is given for each day in the last column.]

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1931	*h m*	°	°	°			
June 1 (Mount Wilson)	10 40	−57.0	106.5	+6.0		314	
		−51.0	112.5	+8.0	5		
		+30.0	193.5	−9.0		6	325
June 2 (Naval Observatory)	10 59	−40.0	110.2	+5.0		154	
		+40.0	190.2	−6.0		31	185
June 3 (Naval Observatory)	11 7	−26.0	110.9	+5.0		201	
		−20.5	116.4	−8.0	6		
		+56.0	192.9	−7.0		15	222
June 4 (Naval Observatory)	10 56	−12.5	111.2	+5.0		216	216
June 5 (Naval Observatory)	11 42	+2.5	112.6	+6.0		278	278
June 6 (Naval Observatory)	10 58	+16.0	113.3	+6.0		278	278
June 7 (Naval Observatory)	10 43	−20.0	64.2	−9.5	3		
		+31.0	115.2	+5.5		355	358
June 8 (Naval Observatory)	11 7	+17.0	117.7	+5.0		185	185
June 9 (Naval Observatory)	11 42	+17.0	74.1	+10.5		46	
		+54.0	111.1	+4.5		93	
		+70.0	127.1	+6.0		62	201
June 10 (Mount Wilson)	13 15	+20.0	63.1	−10.0	1		
		+31.0	74.1	+11.0		28	
		+70.0	113.1	+5.0		58	
		+85.0	128.1	+6.0	29		116
June 11 (Naval Observatory)	10 36	+43.0	74.3	+12.0		31	
		+80.0	111.3	+4.0	31		62
June 12 (Naval Observatory)	11 1	+55.0	72.8	+13.5	6		6
June 13 (Naval Observatory)	11 52	+8.5	12.6	−3.5		46	46
June 14 (Mount Wilson)	11 30	+78.0	69.0	−8.0		42	42
June 15 (Naval Observatory)	13 10		No spots.				
June 16 (Naval Observatory)	11 44		No spots.				
June 17 (Mount Wilson)	17 15	+26.0	334.2	−12.0	4		4
June 18 (Mount Wilson)	9 10	+35.0	334.4	−12.0	4		4
June 19 (Naval Observatory)	10 54	+2.5	287.7	−0.5		15	15
June 20 (Naval Observatory)	10 38		No spots.				
June 21 (Naval Observatory)	10 51		No spots.				
June 22 (Naval Observatory)	11 27		No spots.				
June 23 (Naval Observatory)	10 59		No spots.				
June 24 (Naval Observatory)	10 42		No spots.				
June 25 (Naval Observatory)	10 47	+2.0	207.9	−1.5		31	31
June 26 (Mount Wilson)	18 15	−65.0	123.5	+3.0	7		7
June 27 (Naval Observatory)	10 47	−30.0	149.4	−2.5	9		9
June 28 (Naval Observatory)	10 55	−18.0	148.1	−2.5	12		12
June 29 (Naval Observatory)	11 3	−75.0	77.8	+6.0		123	
		−72.0	80.8	−10.0		62	185
June 30 (Naval Observatory)	10 54	−62.5	77.1	+6.0		108	
		−59.0	80.6	−9.5	62		170
Mean daily area for June							99

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. Gregg in Charge]

By L. T. Samuels

Table 1 contains data for only three stations, aerological observations having been discontinued at Broken Arrow, Okla., and Groesbeek, Tex. It will be noted that free-air temperatures were above normal at the two northern stations, viz., Ellendale and Royal Center, and below normal at Due West. The positive departures increased with altitude, being greatest between 2,000 and 3,000 meters elevation.

Table 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1931*

Altitude (meters) m. s. l.	Due West, S. C. (217 meters) Mean	Due West Departure from normal	Ellendale, N. Dak. (444 meters) Mean	Ellendale Departure from normal	Royal Center, Ind. (225 meters) Mean	Royal Center Departure from normal
TEMPERATURE (°C.)						
Surface	24.5	−0.9	21.4	+2.7	23.0	+1.2
500	21.8	−0.7	21.0	+2.7	21.4	+2.5
1,000	19.6	+0.2	19.4	+4.1	19.5	+3.9
1,500	16.0	0.0	17.8	+5.1	16.6	+3.8
2,000	12.5	−0.2	15.1	+5.3	14.0	+3.8
2,500	9.1	−0.5	11.8	+4.9	11.6	+4.1
3,000	5.6	−0.9	8.4	+4.3	8.9	+4.1
4,000	−2.4	−2.3	2.2	+3.8	2.7	+2.9
5,000	−8.4	−2.3	−4.1	+3.4	−3.1	+3.6
RELATIVE HUMIDITY (%)						
Surface	63	−2	66	−4	71	+5
500	65	−2	65	−4	69	+1
1,000	60	−7	55	−12	65	−4
1,500	63	−6	51	−13	65	−2
2,000	64	−6	50	−12	64	+2
2,500	62	−8	52	−9	62	+6
3,000	61	−7	54	−3	61	+9
4,000	60	0	55	+5	62	+21
5,000	55	0	61	+11	53	+2
VAPOR PRESSURE (mb.)						
Surface	19.74	−0.86	16.82	+1.53	20.54	+3.22
500	17.22	−0.83	16.30	+1.48	17.96	+3.08
1,000	13.98	−0.99	12.20	+0.47	14.96	+2.47
1,500	11.73	−0.81	10.05	+0.62	12.78	+2.51
2,000	9.47	−0.71	8.41	+0.81	10.74	+2.84
2,500	7.21	−0.99	7.17	+0.91	8.86	+3.10
3,000	5.65	−0.77	6.11	+1.28	7.39	+3.10
4,000	3.25	−0.28	4.14	+1.03	5.39	+3.21
5,000	2.32	−0.28	2.76	+0.40	3.60	+1.87

The relative humidity departures were mostly small and negative except at Royal Center, where positive departures occurred with positive temperature departures. This condition is evidently significant in connection with the large amount of precipitation for the month at Royal Center, viz., 8.97 inches, which exceeded all previous amounts for June since the establishment of the station in 1918.

Vapor pressure departures were of the same sign as those for temperature, with the largest departures occurring at Royal Center.

Conspicuous in Table 2 is the low relative humidity at 2,000 and 3,000 meters at San Diego as compared with the other stations. This condition is characteristic of the southwestern part of the country and is probably a consequence of air originating over Mexico.

A noticeable feature of Table 3 is the southwesterly component in the free-air resultant winds over the western part of the country as compared with the northwesterly component over the eastern section.

Table 2.—*Free-air data obtained by airplanes at naval air stations during June, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Florida	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Florida	San Diego Calif.	Washington, D. C.
Surface	22.1	24.3	21.4	21.3	71	82	65	67
500	18.7	22.8	17.7	19.8	66	71	72	58
1,000	16.1	20.2	16.5	17.6	62	62	62	59
2,000	9.7	14.0	14.1	12.3	62	61	36	57
3,000	4.1	8.6	9.0	7.1	62	55	27	51
4,000				0.2				56

Table 3.—*Observations by means of kites, captive and limited height sounding balloons during June, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Royal Center, Ind.
Mean altitudes (meters), M. S. L., reached during month	2,664	2,852	3,387	3,955
Maximum altitude (meters), M. S. L., reached and date	[1] 4,039	[1] 5,090	[1] 5,197	[1] 9,343
Number of flights made	[2] 7	32	30	33
Number of days on which flights were made	[2] 7	28	28	30

[1] Limited-height sounding balloon observation.
[2] Covers period from June 1 to 7, inclusive, only.

In addition to the above, there were approximately 180 pilot-balloon observations made daily at 60 Weather Bureau stations in the United States.

Table 4.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during June, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters) Direction	Velocity	Brownsville, Tex. (12 meters) Direction	Velocity	Burlington, Vt. (132 meters) Direction	Velocity	Cheyenne, Wyo. (1,873 meters) Direction	Velocity	Chicago, Ill. (198 meters) Direction	Velocity	Cleveland, Ohio (245 meters) Direction	Velocity
	°		°		°		°		°		°	
Surface	N 31 E	0.6	S 42 E	1.5	S 5 E	1.0	N 85 W	2.5	S 4 W	1.0	S 5 W	0.9
500			S 24 E	9.2	S 75 W	1.9			S 52 W	3.7	S 53 W	1.5
1,000			S 18 E	7.8	N 33 W	3.7			S 89 W	5.3	N 74 W	2.2
1,500			S 19 E	5.8	N 35 W	4.8			N 86 W	6.6	N 77 W	3.5
2,000	S 30 E	1.1	S 21 E	5.1	N 27 W	6.2	S 84 W	4.5	N 78 W	6.4	N 66 W	5.4
2,500	S 49 W	2.0	S 30 E	3.7	N 33 W	8.3	S 83 W	5.4	N 76 W	5.9	N 60 W	5.0
3,000	S 78 W	3.1	S 66 E	2.7	N 32 W	8.7	N 77 W	6.2	N 87 W	6.4	N 66 W	5.1
4,000	S 71 W	4.0	S 61 E	1.4	N 42 W	9.4	N 70 W	7.8	N 51 W	11.5	N 52 W	5.8
5,000	S 33 W	3.4	N 7 E	1.8			N 83 W	7.5				

Altitude (meters) m. s. l.	Dallas, Tex. (154 meters) Direction	Velocity	Due West, S. C. (217 meters) Direction	Velocity	Ellendale, N. Dak. (444 meters) Direction	Velocity	Havre, Mont. (762 meters) Direction	Velocity	Jacksonville, Fla. (14 meters) Direction	Velocity	Key West, Fla. (11 meters) Direction	Velocity
	°		°		°		°		°		°	
Surface	S 32 E	2.5	W	0.2	S 20 W	0.4	S 68 W	1.4	S 47 W	0.5	N 84 E	1.8
500	S 15 W	9.0	S 79 W	2.2	S 19 W	1.2			S 76 W	2.8	S 86 E	4.5
1,000	S 18 W	7.4	N 70 W	2.4	S 47 W	4.4	S 72 W	3.2	N 81 W	2.3	S 80 E	3.4
1,500	S 24 W	4.6	N 64 W	3.1	S 67 W	4.5	N 89 W	5.8	N 35 W	1.6	S 63 E	2.6
2,000	S 22 W	3.1	N 65 W	4.3	S 63 W	3.9	S 83 W	6.0	N 6 E	2.2	S 27 E	1.6
2,500	S 16 W	2.7	N 64 W	4.3	S 68 W	4.8	S 72 W	6.3	N 11 E	2.2	S 15 E	1.6
3,000	S 15 W	1.5	N 40 W	4.5	N 84 W	5.5	S 75 W	7.3	N 20 E	1.9	S 25 E	1.0
4,000	N 58 W	0.8	N 44 W	6.6	N 84 W	8.9	S 71 W	8.2	N 29 W	2.8	S 38 W	1.1
5,000	N 85 E	1.5	N 36 W	5.7	N 82 W	12.0	S 82 W	10.7	N 38 W	3.6	S 65 W	1.7

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during June, 1931*—Continued

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 84 E	0.6	N 61 W	0.4	S 6 W	1.1	N 6 E	0.3	S 78 W	1.5	S 1 W	2.9	S 32 E	2.3	N 84 E	1.2	S 22 E	2.3	S 78 E	0.8	S 39 E	1.1	N 20 W	1.0
500	S 59 E	1.2	N 79 W	0.5	S 71 W	3.2	N 71 W	0.9	N 83 W	3.1	S 13 W	6.6	S 4 W	5.4	N 88 W	0.3	---	---	S 10 E	1.8	S 13 W	2.5	N 46 W	3.8
1,000	N 46 W	0.9	N 88 W	1.0	S 85 W	3.8	S 36 E	1.5	N 63 W	5.3	S 33 W	10.8	S 44 W	9.0	S 60 W	1.9	---	---	S 56 W	3.4	S 29 W	3.2	N 44 W	4.6
1,500	N 53 W	2.1	S 31 W	1.0	S 74 W	4.0	S 40 E	2.0	N 52 W	4.1	S 40 W	8.5	S 50 W	7.9	S 5 W	1.2	S 13 E	5.2	S 74 W	3.0	S 42 W	3.9	N 52 W	5.8
2,000	S 83 W	2.4	S 33 W	1.8	S 79 W	4.6	S 70 E	1.8	N 77 W	4.6	S 41 W	6.5	S 57 W	6.0	S 9 E	3.0	S 4 W	5.8	S 86 W	3.6	S 41 W	4.6	N 56 W	6.6
2,500	S 19 W	2.7	S 51 W	4.2	S 59 W	4.7	S 76 E	1.4	N 83 W	4.1	S 54 W	3.8	S 51 W	6.2	S 1 W	4.8	S 30 W	6.5	N 82 W	4.6	S 41 W	3.6	N 54 W	6.9
3,000	S 18 W	3.4	S 48 W	6.0	S 47 W	3.7	S 74 E	1.2	S 78 W	4.7	S 58 W	2.8	S 49 W	4.8	S 16 W	6.4	S 48 W	6.5	N 81 W	6.5	S 14 W	4.6	N 50 W	7.3
4,000	---	---	S 53 W	6.8	---	---	N 12 E	1.9	---	---	N 55 W	1.2	S 71 W	3.9	S 29 W	7.5	S 45 W	6.9	N 83 W	9.2	---	---	N 22 W	9.5
5,000	---	---	---	---	---	---	N 86 W	0.9	---	---	---	---	N 63 W	5.6	S 18 W	6.6	S 54 W	11.4	N 65 W	15.4	---	---	---	---

WEATHER IN THE UNITED STATES

[Climatological Division, Oliver L. Fassig in Charge]

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

June as a whole was abnormally warm in the interior and Northwestern States, while moderate temperatures prevailed in much of the South and Atlantic areas. From Oklahoma, Missouri, and Illinois northward and northwestward the monthly mean temperature averaged from 5° to 9° above the normal, the last week being abnormally warm, with the highest weekly mean temperatures of record for June over large areas. The month was likewise abnormally warm along the south Pacific coast, while generally moderate temperatures for the season prevailed in the north Pacific districts.

The precipitation for the month was rather unevenly distributed, with less than the normal over large areas. The Northeast, much of the Lake region, southern Texas, and the Rio Grande Valley received generous to heavy rainfall for the season, and more than normal was received in much of the Pacific region from central California northward. Elsewhere the precipitation was below normal, especially in portions of the Southeast and Northwest. From 10 to 25 per cent of normal was recorded in northern Alabama and Georgia, eastern Tennessee, and portions of the Carolinas, while in portions of southern Idaho only about one-tenth of the normal was received.

TEMPERATURE

From the beginning of the month until a little after the middle the temperature presented no features deserving special notice, although in the far Northwest readings were usually several degrees higher than normal, while comparatively cool weather was noted at times in several portions of the eastern half of the country. This tendency to temperatures below normal was most persistent in some parts of the Lake region and in coast districts between the Rio Grande and Chesapeake Bay.

After the 17th marked heat set in over the southern Plains and the central valleys and prevailed during the remainder of the month, generally increasing in intensity and extending until practically all States from the Rocky Mountain foothills to the Appalachians were under its sway. The Atlantic States were somewhat affected by hot weather, yet mainly were not much warmer than normal during these final two weeks of June, while some districts west of the Continental Divide were experiencing cool weather, particularly the northwesternmost States, during the last week.

The month averaged warmer than normal almost throughout the country, a few areas near Lake Ontario or along the Atlantic or Gulf coast averaging slightly cooler than normal, also much of the far Southwest and part of the State of Washington. From the northern and middle Rocky Mountains eastward to the upper Lakes and the lower Ohio Valley the month averaged at least 3° above normal, and over the northern half of the Plains from 6° to 9° above. The mean temperature was the highest of June record at numerous stations in the northern and middle Plains and the upper Mississippi Valley, while as far to southeastward as Chattanooga, Tenn., it was but slightly below the June record.

The highest marks noted during the last 10 days of June became the record temperatures for all Junes at many stations in the central part of the country.

In general, 100° was reached or passed in every State, save a few small Northeastern States, while some Central Valley States noted marks of 107° to 109°, and South Dakota, 115°. The highest mark reported anywhere in the country was 119° in Arizona. Usually the highest readings occurred during the last three days, but in parts of the upper Ohio Valley and Middle Atlantic States, also the southern Plains, about the 20th, and in the far West on various dates.

The lowest readings of June varied from 48° in several Gulf States to 16° in Oregon, the latter at a high mountain station. Except in the Pacific and northern Rocky Mountain States they usually ocurred during the first 10 days of the month.

PRECIPITATION

In the middle and northern portions of the country between the Rocky Mountains and the Mississippi River the important rains of June occurred at various times in the different States, except the closing week was mainly very dry. To eastward the weeks were about equal in the matter of rains, when the whole area is considered, save the second week which brought little, except in the Lake Superior region and close to the Atlantic coast.

The southeastern and south-central portions of the country had generally scanty rainfall compared with normal, and what occurred fell mainly during the second and third weeks, save that Oklahoma and the Carolina coast had moderate supplies during the first week and

southwestern Texas had decidedly heavy rains during the last week.

In the Pacific Northwest there was practically no rain until the 9th, but afterwards considerable amounts were received, the falls about the 16th being especially liberal and widespread. The San Joaquin Valley in California received considerable rainfall for the time of the year, about the 7th.

Over two-thirds of the States failed to receive their June normal amounts of rainfall. The exceptions were New Jersey and the New England States, Michigan and Wisconsin, and the Pacific States, with Arizona. Massachusetts received more than twice its normal, on the average, Oregon an inch more than normal, and Washington over 2 inches more than normal.

In the States of the western half, which have not been accounted for above, there was usually from a half to four-fifths of the normal June rainfall, but southern Idaho and northern Utah had remarkably little, while the middle and lower Rio Grande Valley had more than normal.

In the lower Mississippi Valley and to eastward decided shortages were noted, especially in northern Georgia and districts adjacent. From Missouri and Iowa eastward the quantities were usually not much below normal, and they generally exceeded the normal in northwestern Indiana and the upper Ohio Valley.

In western Washington 16.39 inches was measured at one station, the largest in the United States proper. In the South, Runge, Tex., measured 12.58 inches, while the East was led by 11.33 inches at a station in Putnam County, N. Y.

SNOWFALL

Scarcely any snowfall was reported from the elevated stations of the Western States, save that a few points in the Sierra Nevada Mountains had measurable falls. It is stated that the northern part of Flathead County, Mont., had an unusually heavy June snowstorm on the 16th and 17th.

SUNSHINE AND RELATIVE HUMIDITY

More than the average amount of sunshine was received from the eastern foothills of the Rocky Mountains eastward to the Atlantic, except in portions of the Lake region, the northern Ohio Valley, the far Northeast, and the western Gulf States. More than normal was likewise received in much of California and southeastern Oregon. Elsewhere it was generally near the average.

The relative humidity was above the normal throughout portions of the Pacific States, the southern plateau, and the southern portion of Texas, the upper Lake region, portions of the Ohio Valley and northern Appalachian Mountains and the New England States. However, in all cases the departures were but slightly above normal. Elsewhere the humidity was generally below normal with minus departures rather pronounced in the southern Appalachian region, the southern portions of the Great Plains, and the northern Rocky Mountains.

SEVERE LOCAL STORMS, JUNE, 1931

The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Olar (near), S. C	1	5:30 p. m.	4 mi.		$65,000	Hail	Severe crop damage; path, 7 miles	Official, U. S. Weather Bureau.
Billings to Ballantine, Mont	2	4–5 p. m.			25,000	Tornadic wind	Damage chiefly to oil refinery	Do.
Bridgewater (near), S. Dak	2	5:30 p. m.	16		500	Small tornado	Cabins destroyed	Do.
Grand Rapids (near), Mich	3					Thunderstorms	Power and telephone service interrupted; several buildings damaged.	Do.
Warren, Ill	3					Wind	Farm buildings and trees damaged	Do.
Lafayette County, Wis. (southern).	4		4 mi.		4,000	Thundersquall	Several barns damaged or demolished; path, 8 miles long.	Do.
Northboro, Iowa (southwest of)	4				875	Tornado and hail	Minor damage to property; poultry killed	Do.
Waushara County, Wis. (eastern)	4	11 p. m.	3 mi.		3,000	Thundersquall	Buildings damaged	Do.
Apple River, Ill., and vicinity	5	12:30 a. m.	4 mi.			Severe wind	Property damaged; several thousand dollars	Do.
Union County, Iowa	5	3–7 a. m.			2,000	Rain and hail	Truck gardens hurt	Do.
Decatur County, Iowa	5	5 a. m.	3 mi.		4,200	Wind, rain and floods.	Buildings and crops damaged; path, 6 miles	Do.
French (near) to Sedan, N. Mex.	5	12:15–6 p. m.		1	30,000	Tornado and hail	Livestock killed; buildings and orchards wrecked; path, 90 miles long.	Do.
Harper County, Okla. (northern)	5	4 p. m.	2 mi.		160,000	Hail	Damage chiefly to crops; path, 24 miles long	Do.
Logan and Thomas Counties, Kans.	5	6 p. m.	1,760		30,000	do	Wheat total loss in places; path, 30 miles long	Do.
Freedom (near), Okla	5	6:20 p. m.			15,000	do	Corps damaged	Do.
Clark County, Iowa	6	2–7 p. m.			3,000	Wind and hail	Greenhouses and crops damaged; path, 12 miles long.	Do.
Knox and Cedar Counties, Nebr.	6	4 p. m.	Up to 2 mi.		65,000	Tornado	Farm buildings demolished; crops injured 10 per cent in places; path, 18 miles long.	Do. Do.
Indiana County, Pa. (central)	6	4–5 p. m.	1,760		10,000	Hail and wind	Many buildings unroofed; orchards and crops badly damaged.	Do.
Waterville, Kans. (5 miles southwest).	6	4:30 p. m.	300		5,000	Small tornado	Farm buildings wrecked; path, 900 yards long	Do.
Salina, Kans., and vicinity	6	5 p. m.	6 mi.		10,000	Hail	Much damage to greenhouses and wheat; path, 15 miles long.	Do.
Lincoln, Nebr	6	5:45 p. m.	2 mi.		80,000	do	Chief damage to roofs, windows and greenhouses; path, 2 miles long.	Do.
Elk (near), Kansas	6	6 p. m.	300		3,000	Tornado and hail	Farm property damaged; path, 10 miles long	Do.
Wilson County, Kans	6	6–7 p. m.			11,000	Hail	Character of damage not reported	Do.
Olathe, Kans., and vicinity	6	7 p. m.	1,760		60,000	Hail and wind	Chief damage to wheat and oats; trees stripped; path 10 miles long.	Do.
Shattuck, Okla	6	7 p. m	3 mi.			do	Heavy crop loss; path, 6 miles long	Do.
Eureka (near)	6	7:30 p. m.	17		100	Small tornado	Small farm buildings damaged; path 1,300 yards long.	Do.
Independence, Kans., and vicinity.	6	8:30 p. m.	900		1,000	Hail	Greenhouses and fruit damaged; path 1 mile long.	Do.
Greensburg, Pa., and vicinity	6	10 p. m.	880		5,000	Wind	Several farm buildings demolished	Do.
Pennsylvania (northeastern)	6	P. m.			250,000	Wind, electrical, hail and rain.	Extensive damage to buildings and other property.	Do.
Evansville, Ind., and vicinity	6					Thunderstorm and wind.	Some delay caused by flooding of streets and sewers; other property damaged.	Do.
Missouri (northwestern)	6		½–4 mi.		75,000	Hail, wind, and rain.	Orchards and field crops severely damaged; windows broken.	Do.
Mounds, Ill., and vicinity	6–7		3 mi.		10,850	Hail	Fruits and vegetables injured 25 to 90 per cent; roofs, auto tops, and tents pierced; path 5 miles long.	Do.

[1] "Mi" signifies miles instead of yards.

Severe local storms, June, 1931—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Pennsylvania (South-central)	7				$100,000	Electrical, wind, and hail.	Buildings unroofed; trees uprooted; stock killed.	Official, U. S. Weather Bureau.
Frederick and Carroll Counties, Md.	7	3:30 p. m.				Wind	Several small buildings unroofed; many trees and a few poles blown down.	Do.
Chickasaw County, Iowa	8	2 a m	1,760		2,000	Hail	Crops injured; path 4 miles long	Do.
Davidson, Okla	8	5 p. m	1,760		2,000	do	Cotton crop injured; path 2 miles	Do.
Duke (near), Okla	9	6 p. m	2.5 mi.		25,000	do	Chief damage to crops; path 4 miles long	Do.
Clark County, Kans	10	4 p. m	3 mi.		15,000	do	Wheat loss 50 to 100 per cent; windows and autos damaged; path 10 miles long.	Do.
Reno County, Kans	10	6:30 p. m.			50,000	do	Farm property severely damaged	Do.
Union (near), Okla	10	7 p. m			25,500	do	Considerable crop loss; minor property damage.	Do.
Glasco (near), Kans	10	8 p. m			1,000	Small tornado	Residence and implement shed wrecked; path 4 miles long.	Do.
Concordia to Belleville, Kans	10	8:30 p. m.			500	Violent wind and probably small tornado.	Number of small buildings unroofed	Do.
Mayfield, Kans., and vicinity	10	P. m	3 mi.			Hail	Wheat total loss; other crops badly injured; path 7 miles long.	Do.
Pryor, Okla., and vicinity	11	2:30 p. m.	2 mi.		12,000	do	Chief damage to crops; path 8 miles long	Do.
Rochelle (near), Tex	11	4 p. m	150			Tornado	4 persons injured; character of damage not reported.	Do.
San Saba (near), Tex	11	5 p. m	2,640			Hail	Crops damaged; livestock killed	Do.
Greenville, Commerce, and Cooper, Tex.	11	6:45 p. m.	12 mi.			Wind	Buildings unroofed; chimneys, poles, and trees blown down.	Do.
Deport, Tex	11	8 p. m			10,000	do	Buildings damaged	Do.
Princeton (near), Tex	11	8:30 p. m.	1,320		1,000	Wind and hail	Some damage to buildings and crops	Do.
Boone County, Nebr. (western)	12	3 p. m	1,760		9,000	Hail	Considerable crop damage in places	Do.
Brownfield (near), Tex	12	7 p. m	2 mi.		5,000	do	Crops ruined	Do.
Kossuth County, Iowa	12	10 p. m	4 mi.		4,000	Wind	Windmills and buildings damaged; path, 6 miles long.	Do.
Tupelo (near), Miss	12	11 p. m				Probably tornado.	Crops and trees damaged	Do.
Hamlin (near), Tex	12	P. m	3 mi.			Hail	Crops ruined	Do.
Princeton, Ind	12				3,000	Wind	Buildings damaged	Do.
Sherman County, Kans. (eastern).	12	P. m			6,000	Hail	Wheat injured	Do.
Duplin County, N. C. (northwestern).	13	5 p. m	880		100,000	Hail and wind	Damage chiefly to crops; 4 barns and other small buildings blown down.	Do.
Albemarle County, Va. (southwestern).	13	8:30-11:30 p. m.	½-6 mi.		30,000	Hail	Fruits, chiefly apples, damaged	Do.
Garden City, Kans	13					do	4,000 acres of wheat damaged	Do.
South Byron, N. Y	14	3-5 p. m	2,640		10,000	do	Peas and tomatoes damaged	Do.
Rush Center and vicinity, Kans.	14	4-5 p. m	2 mi.		10,000	do	Wheat damaged 40 per cent; path, 5 miles long.	Do.
Amarillo, Tex. (east of)	14	6 p. m			10,000	do	Considerable crop damage	Do.
Spearman (near), Tex	14	6:30 p. m.	2 mi.		50,000	do	Much loss to crops	Do.
Rice and Reno Counties, Kans	14	7-9 p. m	4 mi.		600,000	do	Heavy damage to wheat, apples, and gardens; windows and auto tops pierced; path, 35 miles long.	Do.
Harvey County, Kans	14	9-9:30 p.m.	2 mi.		70,000	do	Heavy damage to automobiles, roofs, and windows; traffic delayed; path, 12 miles long.	Do.
Hancock County, Ga. (southern)	14				2,000	do	Crops injured	Do.
Buffalo, N. Y	14					Wind and thunderstorm.	House blown down and large smokestack damaged.	Do.
Waycross, Ga	14				5,000	Wind	Church demolished and several roofs blown off; 2 persons injured.	Do.
Bickleton, Wash	15	6:30 p. m.	1,760		5,000	Hail	Grains, gardens, shrubbery, and windows damaged.	Do.
Montezuma, Ga	15					Wind	Small barns, tenant house, and church wrecked.	Do.
Trenton, S. C	15				6,000	Thunderstorm	Cotton gin burned	Do.
Montana (northwestern counties)	16				16,300	Hail	Damage chiefly to crops	Do.
Dallas, Tex	17	5:10 p. m.			60,000	Thunderstorm	Oil tank struck by lightning and burned	Do.
Doretta, Mont	17	Noon	2 mi.			Hail	Considerable damage, character not reported	Do.
Clay and Chickasaw Counties, Iowa.	18	11:30 p. m.-midnight.			22,000	Wind	Buildings wrecked	Do.
Winneshiek, Wayne, and Benton Counties, Iowa.	19	A. m			14,500	do	Buildings and crops damaged	Do.
Wessington (near), S. Dak	19	4:30 p. m.	880		32,500	Tornado and hail	Farm buildings wrecked	Do.
Davison to Lake County, S. Dak.	19	7 p. m	10 mi.		12,000	Wind and hail	Windmills blown down; crops and farm buildings damaged.	Do.
Kossuth County, Iowa	19	10 p. m			500	Tornado	Buildings damaged	Do.
Mallard (near), Iowa	19	do			7,300	do	Damage chiefly to farm property; path, 1 mile long.	Do.
Sioux Rapids (near), Iowa	19	do	67			Tornado and wind.	Property on 5 farms damaged; path, 5 miles long.	Do.
Hayfield (near), Iowa	19	10:30 p. m.		1	24,000	do	Trees, buildings, and telephone equipment damaged; 4 persons injured; path, 6 miles long.	Do.
Deerfield (near) to Alta Vista, Iowa.	19	11-11:30 p. m.			70,000	do	Buildings and crops heavily damaged; livestock killed or injured.	Do.
Waterloo, Iowa	19	11:40 p. m.	267		8,000	Tornado	Character of property damaged not reported; path, 2 miles.	Do.
Garwin (near), Iowa	19	11:45 p. m.			1,200	do	Buildings and trees damaged; path, 6 miles long.	Do.
Carroll and Cherokee Counties, Iowa.	19				45,000	Wind and hail	Considerable damage to crops	Do.
Lyndonville and Wilson, N. Y	19				14,000	Electrical	Several buildings burned	Do.
Whitehall (near) and Neilsville (near), Wis.	19				3,000	Thunderstorm and hail.	Several barns and other farm buildings damaged.	Do.
Jerico, Iowa (north of)	20	12:15 p. m.			13,000	Tornado and wind.	Buildings and crops damaged; path, 7 miles long.	Do.
Walthill, Nebr. (4 miles southwest).	20	4 p. m	880			Hail	Crops considerably damaged; path, 1 mile long.	Do.
Cass, Pottawattamie, Shelby, and Humboldt Counties, Iowa.	20	P. m			208,000	Wind and hail	Heavy crop loss; buildings damaged	Do.
Central and southern counties, New York.	20	do		1		Severe electrical and wind.	Many trees blown down; several barns wrecked; much damage to roofs, buildings, and wires; livestock killed.	Do.
Green and Sac counties, Iowa	20				6,000	Hail	Crops damaged	Do.
Guthrie, Harrison, Hancock, Linn, and Winneshiek Counties, Iowa.	20				24,000	Wind	Crops and buildings damaged	Do.
Montana (southeastern counties)	21					Hail	Growing crops hurt	Do.
Pocahontas County, Iowa	22	1:30-2 p.m.			25,000	Wind and hail	Crops damaged	Do.
Newton, Ill., and vicinity	22	3:30 p. m.				do	Number of buildings damaged; poles and trees blown down, electric service interrupted; fruit and grain crops hurt.	Do.

Severe local storms, June, 1931—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Marshall County, Iowa	22	9 p. m.			$14,000	Wind	Buildings, fruit trees, and crops injured	Official, U. S. Weather Bureau.
Elgin (near), Ill	22					Wind and rain	Wheat and oats on several farms almost a total loss.	Do.
De Kalb County, Ill. (northern)	22					Wind, hail, and rain.	Oats, hay, fruit, and gardens almost total loss in places; roofs damaged; wire services interrupted.	Do.
Dubuque, Iowa	22					Wind	Factories and residence considerably damaged	Do.
Macoupin County, Ill. (central)	22					do	Several buildings damaged; trees and wheat blown down.	Do.
Montana (northeastern counties)	22					Hail	Growing crops damaged	Do.
Hopkins, S. C	23	9–10 p. m.			3,000	Hail and wind	Crops, cabins, and outbuildings damaged	Do.
Montana (south-central counties)	23					Hail	Growing crops damaged	Do.
Evansville, Ind., and vicinity	24				30,000	Electrical	Telephone lines, homes and other buildings damaged.	Do.
Franklin County, Miss	24			1		Thunder squall	Residences damaged	Do.
Statesboro (near), Ga	25					Wind	Several tobacco barns damaged; many trees blown down.	Do.
Michigan (straits to southern boundary).	26	4:30–9 a. m.		2		Wind, electrical and rain.	Many buildings damaged; trees uprooted	Do.
Sunbury, Pa., and vicinity	26				10,000	Electrical	Garages and autos wrecked; crops damaged	Do.
Ohio (northern)	26–27			4		Thunderstorms and wind.	Extensive destruction of property of all kinds; Cleveland hardest hit; 1 person injured.	Do.
Montana (east-central counties)	28					Hail	Crops damaged	Do.
Kettle Falls, Wash	29	2:30 p. m.			25,000	Thunder and hail	Chief damage to apple crop	Do.
Thomas to Sedan (near), N. Mex.	29	3-4:15 p.m.				Hail	Considerable damage, character not reported; path 15 miles long.	Do.
Rock Hill, S. C	29	P. m.			3,000	Hail and wind	Character of damage not reported	Do.
Montana (north-central and central counties.)	29				100,000	Hail	Severe crop damage	Do.
Indiana	29					11 severe wind storms.	Character of damage not reported	Do.
Bunker Hill, Ill	30	6 p. m.	3 mi.		10,000	Wind	Buildings damaged or wrecked; poles and trees blown down; crops flattened; path 5 miles.	Do.
Gordo (near), Ala	30					Wind and hail	Number of small buildings wrecked; trees uprooted.	Do.
Hernando, Miss., and vicinity	30				3,000	Violent wind and hail.	Character of damage not reported	Do.
Literbury, Ill., and vicinity	30					Wind and rain	Small buildings and crops damaged; 2 persons injured.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

Many of the rivers in the mid-western and far-western States were still at very low stages in June, and in no part of the country were there any river rises of importance. Heavy rains in northeastern Missouri and southern Kansas overflowed creeks, and caused damage estimated at $9,000 in Missouri and $4,000 in Kansas.

Table of bankful stages in June, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Connecticut: Hartford, Conn	16	10	13	17.6	11
MISSISSIPPI SYSTEM					
Upper Mississippi Basin.					
Illinois: Peru, Ill	14	25	25	14.1	25
Arkansas Basin.					
Fountain: Fountain, Colo	8	25	25	8.6	25
GULF OF CALIFORNIA DRAINAGE					
Colorado: Parker, Ariz	7	1	30	8.0	10–15
PACIFIC SLOPE DRAINAGE					
Columbia Basin.					
Columbia: Marcus, Wash	24	12	16	24.2	13, 14

THE WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

F. A. Young, Temporarily in Charge, Marine Division

NORTH ATLANTIC OCEAN

By F. A. Young

With the exception of a tropical disturbance of slight intensity and a few local squalls, that will be described later, the North Atlantic during the current month was unusually free from heavy weather. Up to the time of writing only 15 vessels have rendered storm reports, and of these only 2 recorded a wind force as high as 10, while gales were not reported on more than one day in any 5° square.

There was an intrusion of low pressure over the region usually occupied by the North Atlantic high during the first 12 days of the month, while from the 13th to the 30th this center of action was well developed.

The number of days on which fog was reported in different sections of the ocean is as follows: Over the Grand Banks, from 10 to 15 days; along the American coast, north of the thirty-fifth parallel, from 12 to 19 days; over the northern steamer lanes, between the tenth and forty-fifth meridians, from 3 to 5 days; along the European coast, from 1 to 9 days.

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m (seventy-fifth meridian), North Atlantic Ocean, June, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[1] 30.07	(2)	30.48	3d	29.64	24th.
Belle Isle, Newfoundland	29.92	[3] +0.08	30.42	9th	29.14	23d.
Halifax, Nova Scotia	29.92	[4] −0.05	30.20	26th	29.60	21st.[5]
Nantucket	29.94	[4] −0.06	30.20	22d [5]	29.66	8th.
Hatteras	30.02	[4] 0.00	30.20	26th	29.60	8th.
Key West	29.99	[4] +0.01	30.10	3d	29.88	8th.[5]
New Orleans	30.03	[4] +0.03	30.14	3d	29.88	8th.
Cape Gracias, Nicaragua	29.84	[3] −0.05	29.94	2d	29.80	28th.[5]
Turks Island	30.04	[4] +0.01	30.12	18th	29.94	8th.[5]
Bermuda	30.05	[4] −0.08	30.26	23d	29.84	29th.
Horta, Azores	30.15	[3] −0.06	30.50	22d	29.62	2d.[5]
Lerwick, Shetland Islands	29.92	[3] +0.12	30.32	4th	29.35	15th.
Valencia, Ireland	29.98	[3] −0.02	30.39	29th	29.49	10th.
London	30.04	[3] +0.11	30.39	25th	29.54	13th.

[1] Average of 28 observations.
[2] No normal available.
[3] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[4] From normals based on 8 a. m. observations.
[5] On other date or dates.

On the 1st there was a fairly well developed low of limited extent, central near 43° N., 25° W., that drifted slowly northeastward, decreasing in intensity. From that date until the 5th a few vessels in the eastern section of the steamer lanes reported winds of force 7 to 9, although moderate weather prevailed over the greater part of this region, as well as over the remainder of the ocean.

From the 6th to 8th moderate gales were again reported between the forty-fifth meridian and the Azores. On the 9th one of the most severe disturbances of the month was central about 300 miles north of the Bermudas; this moved but little during the next 24 hours, and on the 10th moderate westerly gales were encountered by a number of vessels between the fortieth and forty-fifth parallels.

From the 11th to 13th moderate weather, with comparatively high pressure, was the rule over the greater part of the ocean, and no storm reports were received for that period.

On the 14th and 15th an area of low pressure was over the steamer lanes, east of the thirtieth meridian, and moderate southwesterly gales occurred over a limited area.

From the 16th to 24th there ensued a period of unusually quiet weather over practically the entire ocean, with the exception of a moderate low on the 21st, central near 43° N., 52° W.

On the 25th a depression was over the peninsula of Yucatan, that afterwards developed into a moderate tropical disturbance. On the daily weather map for June 26 it is stated: "A disturbance of moderate intensity is apparently central in the south-central portion of the Gulf of Mexico." On the 27th the center of this disturbance was about 100 miles east-northeast of Brownsville, Tex., and on the 28th over the coast of western Texas. The Honduran steamship *Choluteca* was the only vessel rendering a report of this storm, as shown in table.

Charts VIII to X cover the period from the 23d to 25th, inclusive. Charts VIII and IX give an idea of the weather encountered by Messrs. Post and Gatty on the first two days of their around-the-world flight, and Chart X is drawn to show the conditions on the 25th, when Messrs. Hillig and Hoiriis landed in Germany.

Notes.—British steamship *Olna;* captain, P. Skone-Rees; observer, Sydney Mitchell, chief officer. Montreal to Port Arthur:

June 19, 1931, from 4 p. m. to 5:30 p. m. A. T. S.: A heavy electrical storm; clouds, Ci.-Cu., Cu. and Cu.-Nimb. Continual thunder and lightning. Occasional squalls traveling from NW. to SE., with an inclination to the southward and SW. This was preceded by a remarkable display of waterspouts, as many as five being seen at the same time and reforming as quickly as they dispersed. Position, between 24° 25′ N., 82° 08′ W., at beginning to 24° 25′ N., 82° 20′ W., at end.

Greek steamship *Okeania;* captain, Isadore M. Carivalis; observer, Master. Gibraltar to Baltimore:

Waterspout, June 4, in 36° 14′ N., 56° 37′ W., 6:30 p. m. ship time. Observed waterspout on starboard bow (ship course west) 3 miles distant. Lasted until 7:30 p. m. Barometer 29.81 (corrected); clouds Cu.-Nb. from SW., 7 to 10. Air temperature, 66; water, 72.

American steamship *San Julian;* captain, G. V. Spankie; observer, M. Sander, chief mate. From Philadelphia to Canal Zone:

June 29, 3:30 a. m. E. S. T., in 16° 00′ N., 75° 40′; wind NW., 4. Vessel entered very heavy electrical disturbance. Lightning, thunder, and torrential rain; wind calm and variable. At 7 a. m. in 15° 30′ N., 75° 50′ W., wind SE., 3, then to NE., 3, and calm in afternoon. About one hour before entering this, wind had been NE., 4, then shifted to NW. When near the center the thunder and lightning were almost continuous.

OCEAN GALES AND STORMS, JUNE, 1931

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Aracataca, Br. S. S	Rotterdam	Tela, Honduras.	39 16 N	32 20 W	June 1	Noon 2	June 3	29.63	SSW	SSW, 9	NW	SSW, 9	SSW-NW.
Ogontz, Am. S. S	Pasajes, Spain.	New Orleans	35 20 N	38 40 W	June 6	Mdt. 6	June 7	29.75	SW	W, 6	W	W, 8	SW-W-WNW.
Cripple Creek, Am. S. S	New Orleans	Liverpool	38 47 N	64 42 W	June 9	2 p. 9	June 9	29.48	E	E, 10	S	E, 10	E-SE-S.
Marie Leonhardt, Ger. S. S.	New York	London	40 33 N	60 23 W	do	— 9	do	29.88	E	E, 9	E	E, 9	Steady.
Berlin, Ger. S. S	Bremerhaven	New York	48 43 N	22 15 W	June 14	Mdt. 14	June 15	29.31	SSW	SSW, 10	NW	SSW, 10	SSW-W.
Nieuw Amsterdam, Du. S. S.	Rotterdam	do	50 43 N	15 03 W	June 15	8 a. 15	do	29.47	SSW	SSW, 8	WSW	SSW, 8	SSW-WSW.
Tulsa, Am. S. S	Savannah	Liverpool	39 49 N	53 38 W	June 21	2 a. 21	June 21	29.72	SSW	SSW, 8	SSW	SSW, 8	Steady.
Choluteca, Hond. S. S	Baltimore	Tela, Honduras.	20 32 N	85 38 W	June 25	7 a. 25	June 25	29.59	E	SE, 6	SE	SE, 8	
Okeania, Gr. S. S	do	Lisbon	39 54 N	51 12 W	June 24	Noon 25	do	30.02	SSW	SW, 6	NW	SW, 8	S-SW.
San Tirso, Br. S. S	Minatitlan	Manchester	40 25 N	55 14 W	June 27	3 p. 28	June 28	29.71	WSW	S, 6	S	SSE, 8	
NORTH PACIFIC OCEAN													
Emma Alexander, Am. S. S.	San Francisco	Seattle	41 14 N	124 33 W	June 3	2 p. 3	June 3	29.98	NW	—, 8	NW	NW, 9	WNW-NW..
Iowa, Am. S. S	Japan	San Francisco	41 48 N	157 37 E	June 4	8 p. 4	June 5	29.36	ENE	NE, 7	NW	WNW, 8	NE-N-NW.
Paris Maru, Jap. S. S	Seattle	Yokohama	52 53 N	149 02 W	do	Mdt. 4	do	29.18	S	S, 8	SSW	S, 9	3 pts.
Granville, Pan. M. S	Shanghai	San Pedro	45 54 N	163 30 W	June 10	8 p. 10	June 14	[1]29.54	E.	E, 8	WNW.	WNW, 9	
City of Elwood, Am. M. S.	do	Honolulu	31 30 N	154 08 E	June 11	5 a. 12	June 12	29.20	SE	S, —	SW	S, 8	SE-S.
Tejon, Am. S. S	Yokohama	San Pedro	42 00 N	139 00 W	do	— 13	June 13	29.37	SE	NE, 8	W	—, 9	
Golden Tide, Am. S. S	Hong Kong	San Francisco	34 24 N	140 16 E	June 12		June 12	29.60	ESE		S	ESE, 9	ESE-S.
Olympia, Am. S. S	Orient	do	43 16 N	169 50 W	do	— 13	June 14	[1]29.44	E	S, 8	SW	S, 8	SE-S-SW.
City of Victoria, Can. S. S.	Japan	do	39 48 N	168 32 W	June 16	Noon 16	June 17	29.74	SE	SE, 7	SSW	—, 8	
Seattle, Am. S. S	Celebes	do	39 15 N	157 55 W	June 22	5 a. 23	June 23	29.79	S	SW, 6	SW	SW, 8	S-SW-W.
Iowan, Am. S. S	Los Angeles	Balboa	16 59 N	103 16 W	June 23	6 a. 23	do	29.75	SE	SE, 6	SSE	E, 8	SE-E
Blythmoor, Br. S. S	Vancouver	Panama	19 48 N	106 29 W	June 24	10 p. 24	June 24	29.74	NW	E, 8	SE	E, 8	N-E-SE.

[1] Barometer uncorrected.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—During June, 1931, the Aleutian LOW was slightly deeper than normal for the month, especially to the westward of the peninsula of Alaska, where also the pressure was lower than in the previous month, thus showing an early summer intensification. On the average a distinct center of 29.81 inches barometer extended from the Gulf of Alaska westward to beyond Dutch Harbor. During strongest developments of the LOW the barometer fell to a minimum of 29.10 inches at Kodiak on the 5th, and to 29.02 at Dutch Harbor on the 15th.

The North Pacific HIGH covered an extensive area in middle latitudes over the eastern half of the ocean throughout the month, its eastern extremity lying along the coast of the United States except on five or six days, when the northern LOW intervened by extending unusually far southward. Over the western part of the ocean in these latitudes pressure was fluctuating and unstable.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, at indicated hours, North Pacific Ocean and adjacent waters, June, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1] [2]	29.99	0.00	30.20	8th [3]	29.74	11th.
Dutch Harbor [1]	29.81	−0.09	30.26	13th	29.02	15th.
St. Paul [1]	29.88	+0.02	30.30	13th	29.12	15th.
Kodiak [1]	29.81	−0.10	30.16	1st [3]	29.10	5th.
Midway Island [1]	30.04	−0.01	30.16	19th [3]	29.74	3d.
Honolulu [4]	30.06	+0.02	30.15	17th	29.93	6th.
Juneau [4]	29.93	−0.08	30.32	3d	29.48	21st.
Tatoosh Island [4] [5]	29.99	−0.06	30.25	4th	29.73	25th.
San Francisco [4] [5]	29.96	0.00	30.11	16th	29.81	4th.
San Diego [4] [5]	29.92	+0.03	30.03	15th	29.74	22d.

[1] P. m. observations only used in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] And on other date or dates.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Depressions and gales.—June witnessed comparatively quiet weather over the entire North Pacific, with an absence of tropical storms, as well as of gales exceeding 9 in force, so far as now indicated by reports.

In east longitudes, particularly toward the Asiatic coast, numerous tropical and extratropical depressions gathered, those in lower waters dissipating or moving out of the field without much show of energy. In the Japanese area only one cyclone of the month is indicated as displaying marked strength. This skirted the lower coast of Japan and caused gales of force 8 to 9 on the 12th from Kiushu Island to southeastern Honshu.

A depression lying north of Midway Island on June 1 moved into the Aleutian region on the 2d, and thence into the Gulf of Alaska on the 4th and 5th, where isolated southerly gales of force 9 were reported near 53° N., 148° W., during the time of greatest intensification of cyclonic energy over the northeastern part of the ocean for the month.

From the 11th to 14th a series of gales of force 8 to 9 was encountered along the northern routes between about latitudes 40° and 50° N., longitudes 135° and 170° W. These were caused by two depressions, the more easterly of which lay south of the Gulf of Alaska for two or three days, becoming more and more restricted in area until, as a small LOW, it entered the Washington-Oregon coast on the 15th. The other depression entered the Aleutian area from the southwest on the 13th, causing fresh gales along its eastern boundary on that date. By the 15th, then central in the southern part of the Bering Sea, it acquired considerable depth, giving the lowest pressure of the month over the central Aleutians, and a reported gale of force 9 from the west nearly south of Atka Island.

On the 3d and 4th of the month there was a strong northwesterly air current off the American coast between Tatoosh Island and Eureka, blowing along the eastern edge of the HIGH and rising in force at times to that of a fresh to strong gale.

In the Mexican coast region, during the prevalence of slight depressions over lower and upper Mexico, a fresh

easterly gale was experienced on the 23d off Acapulco, a moderate gale in the Gulf of Tehuantepec on the 24th, and a fresh easterly gale on the same date off central Lower California. Aside from these, no gales were reported from the entire ocean south of the thirtieth parallel.

Winds at Honolulu.—While there were some southerly winds at Honolulu early in June, due to the depression then west and northwest of the Hawaiian Islands, the prevailing direction for the month was east, with the maximum velocity, 24 miles from the east, on the 22d.

Fog.—In the average year fog increases greatly in frequency and extent over the upper waters of the North Pacific, especially along the western part of the routes, during June. This year the June percentage of fog was slightly less than in the previous May over the region of the summer fog bank lying east and southeast of the Kuril Islands, except in the 5° square, 43° to 48° N., 155° to 160° E., where it occurred on 10 days, or with about its frequency in the previous month. Along the middle part of the upper routes the occurrence was light, but south of the Gulf of Alaska, from longitude 150° W. to the coast, it was encountered on three to five days in each 5° square. The heaviest coastal occurrence was between Eureka and San Diego, where it was reported on nine days. Farther southward it was met with occasionally to Cape San Lucas. In mid-ocean, between 30° and 35° N., 165° E. to 165° W., fog was unusually frequent, forming here and there along the strip from the 17th to the 27th.

Volcanic phenomena.—The British steamer *Narenta* was in port of San Jose de Guatemala during the day of June 5. Mr. C. K. Brown, third officer of the vessel, on this day reported: "Volcano Isalco in eruption. Lava flowing freely down side like a waterfall. Visible at 50 miles through rain."

Mr. F. E. Holmes, observer on the American steamer *Victoria*, reported in June (date not given, but between the 8th and the 26th): "While laying at the dock at False Pass, Alaska, latitude 54° 51′ N., longitude 163° 22′ W., noted some fine brown sand or lava falling, evidently from Volcano Shishaldin."

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for June of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the June, 1930, means from the 11-year means for June, 1920–1930, and the changes from the temperatures for the preceding month of May, 1930.

The chart shows the number of observations taken during the month of June, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

[1] In 3 cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

June marks the end of what may be called the cool season in the Caribbean Sea. From the 1st to about the middle of the month, under average conditions, the seasonal march of sea-surface temperatures continues to exhibit nearly as strong an upward trend as that found in May, but this rapid rise does not continue through the rest of the month. Instead, it becomes more gradual than is found in the first half of June, in the spring weeks, or in the late summer. The Straits of Florida region, hitherto cooler than the Caribbean Sea, becomes the warmer of the two areas, with the time of the reversal in relative temperature varying from early June to near the beginning of July.

In average years within the Straits of Florida, June is the month of most rapid rise in temperature during the entire year, with the 11 years' record showing no June as cool as the warmest May.

Comparing the two areas by quarter months, the Caribbean has usually been warmer than the Straits during the first quarter of June; as often the cooler as the warmer during the second quarter, although its temperature averages slightly higher for the 11 years; cooler than the Straits during the third quarter, with exceptions in 1926 and 1930; and at no time warmer during the fourth quarter, unless the doubtful case of 1919, when observations were few, be included. In the Straits of Florida the third and fourth quarters of June have thus been almost uniformly periods when the surface water was distinctly warmer there than in the Caribbean Sea, with the result that the Straits show a higher mean temperature for the month.

In June, 1930, the Caribbean Sea was somewhat cooler than average east of the seventieth meridian, close to the average in the Cuba-Jamaica region and north of the eastern Colombia coast, and warmer than the 11 year mean over the rest of the sea, with the plus departures large in Central American waters. The fourth quarter of June was cooler than the third over the region east of the seventy-fifth meridian, and in that area west of this longitude and south of the fifteenth parallel. For the fourth successive month the mean temperature of the sea as a whole was somewhat above the seasonal average.

In the Straits of Florida, June was notably an abnormal month. The observational readings for the first and fourth quarters gave computed mean temperatures well below the usual values, while those for the second and third quarters and for the month as a whole averaged the lowest for these periods since records began.

This coolest June in the Straits area followed a month with sea-surface temperatures, within the range of statistical possible error arising from limited size of samples, as high as in any preceding May, the difference between these two months in 1930 being only 0.8°. The smallness of this May-to-June range in temperature constitutes another record without precedent or near approach. The anomaly of this near approach to equality between the two monthly temperatures becomes increasingly manifest when the 0.8° difference is contrasted with the mean range of 2.9° between May and June for the 10-year period of 1920 to 1929.

No theory is offered in explanation for, or in support of, a cause-and-effect relation between the cool water in June in the Straits of Florida and the 1930 drought. The period covered by sea-surface temperature records in workable volume includes only a few recent years, and

conclusions would be difficult to draw if not quite impossible to verify to any accurate degree. The coincidence, however, of extreme conditions—low temperature in the Straits of Florida surface waters and scanty precipitation in the regions receiving ultimately nearly all their rainfall from the Gulf of Mexico and western North Atlantic sources—is interesting in its implications.

Dr. C. F. Brook's analysis of thermograms from the condenser-intake of the *Henry M. Flagler*,[2] paralleling in every respect, as it does, the results from the Weather Bureau records in regard to temperature marches, and agreeing with them in absolute values to well within the limits of differences to be expected in data not completely comparable, lends support to the reality and amplitude of the computed temperature anomaly.

Table 1.—*Lengths of "quarter months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[2] This ship, a car ferry plying between Key West and Habana, installed thermographic equipment in 1928, from the records of which equipment Doctor Brooks made his study. Due to lay-overs in dock by the ship, the records were somewhat fragmentary. The study was brought to a close with the June 3-9 record in 1930. The periods available for comparisons in the present writing were: May 27-June 2, 1929; June 17-23, 1929; May 27-June 2, 1930; and June 3-9, 1930. Cf. Charles F. Brooks. Gulf Stream daily thermograms across the Straits of Florida. Monthly Weather Review, April, 1930, 58 : 148-154; and Charles F. Brooks and Edith M. Fitton. Weekly succession of Gulf Stream Temperatures in the Straits of Florida. Ibid July, 1930, 58 : 273-280.

Table 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for June, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
		°F.		°F.
1919 [1]	65	82.2	32	81.1
1920	208	81.1	25	81.0
1921	169	81.1	54	81.3
1922	181	80.5	98	81.8
1923	348	80.4	97	81.1
1924	347	82.0	109	82.8
1925	570	81.2	141	81.5
1926	468	82.1	138	81.6
1927	399	81.8	143	82.4
1928	691	81.6	167	81.8
1929	839	81.2	186	81.4
1930	658	81.5	147	80.4
Mean (1920–1930)		81.3		81.6

[1] Not used in computations because of insufficient data available.

Table 3.—*Mean sea-surface temperatures (°F.) and number of observations, June, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	June 1–7	144	81.2			38	80.2		
II	June 8–15	183	81.5			34	79.6		
III	June 16–22	148	81.7			36	80.2		
IV	June 23–30	183	81.7			39	81.8		
Month		658	81.5	+0.2	+0.5	147	80.4	−1.2	+0.8

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, June, 1931

[For description of tables and charts, see February, 1931, REVIEW, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	79.9	+1.7	Talladega	109	28	St. Bernard	44	2	1.49	−2.91	Silverhill	4.67	Centerville	0.17
Arizona	76.3	−0.4	Gila Bend	119	30	Alpine	25	5	0.70	+0.32	Canille	3.58	8 stations	0.00
Arkansas	78.3	+1.4	Amity	107	30	Dutton	35	1	2.60	−1.50	Hot Springs	6.03	Big Lake Outlet	0.36
California	66.6	−0.9	Greenland Ranch	116	24	Ellery Lake	25	16	0.77	+0.46	Kennett	3.88	12 stations	0.00
Colorado	64.9	+3.5	Las Animas	110	23	Pearl	23	[1] 4	1.25	−0.26	Arriba	4.03	Sunbeam	0.05
Florida	80.0	+0.2	Monticello	109	29	Vernon	48	9	2.12	−4.49	Everglades	5.25	2 stations	0.00
Georgia	80.4	+2.5	2 stations	109	[1] 28	Tallapoosa	41	9	1.80	−2.68	Clayton	5.15	Fitzgerald	0.01
Idaho	63.3	+2.8	Orofino	103	7	Atlanta	23	24	0.63	−0.60	Bismarck Ranger Station.	2.82	3 stations	0.00
Illinois	75.3	+3.7	2 stations	107	[1] 29	Danville	37	1	3.17	−0.76	Quincy	7.88	Carbondale	0.34
Indiana	73.9	+2.7	Edwardsport	109	28	Delphi	34	1	3.61	−0.25	Royal Center	8.97	Mauzy	1.31
Iowa	75.0	+5.7	2 stations	106	28	Estherville	36	8	3.73	−0.77	Waukee	8.11	Cedar Falls	1.31
Kansas	77.8	+4.8	do	106	[1] 20	Tribune	44	7	2.15	−1.91	Eldorado	7.72	Johnson	T.
Kentucky	75.3	+1.5	Henderson	106	29	Mount Sterling	39	2	2.79	−1.46	Oneonta	5.49	2 stations	1.31
Louisiana	79.7	−0.4	Lake Providence	105	29	2 stations	48	2	2.02	−2.79	Hammond	5.20	Logansport	0.00
Maryland-Delaware	70.8	0.0	Cumberland, Md	102	20	Sines, Md	35	10	3.43	−0.50	Westminster, Md	5.93	Cumberland, Md	1.37
Michigan	66.7	+3.1	Seney	103	30	Wolverine	20	1	3.40	+0.28	Albion	7.67	Gladwin	0.91
Minnesota	69.5	+5.5	Canby	110	29	Big Falls	28	1	3.95	−0.08	Tower	8.71	Roseau	1.25
Mississippi	79.7	+1.0	Columbus	108	30	4 stations	48	[1] 2	2.32	−1.89	Columbia	7.95	Rosedale	0.19
Missouri	77.1	+3.9	Marble Hill	107	29	2 stations	40	[1] 1	2.94	−1.93	Philadelphia	9.14	Osceola	0.56
Montana	64.2	+4.4	Frazer	110	16	Loweth	20	24	1.34	−1.20	Glendive	3.25	Augusta	0.38
Nebraska	75.7	+6.7	Santee	109	28	Mullen	35	[1] 5	2.43	−1.35	Weeping Water	6.14	Lyman	0.20
Nevada	67.0	+1.5	Clay City	112	11	Zorra Vista Ranch	27	28	0.48	−0.01	Lewers Ranch	1.69	2 stations	0.04
New England	64.3	+0.5	Turners Falls, Mass.	100	30	Pittsburg (a), N. H.	32	22	5.45	+2.07	Swampscott, Mass.	10.81	St. Albans, Vt.	2.27
New Jersey	69.3	+1.0	Newton	101	20	Runyon	40	3	4.84	+0.96	Boonton	7.42	Bridgeton	2.18
New Mexico	69.6	+1.2	Cambray	108	20	Luna Ranger Station.	25	5	0.76	−0.56	Quemado	3.20	3 stations	0.00
New York	65.3	+0.6	Dansville	100	30	Indian Lake	29	2	3.45	−0.25	Boyds Corners	11.33	Syracuse	1.15
North Carolina	74.0	+0.2	Fayetteville	105	29	Mount Mitchell	30	9	2.55	−2.24	Kenansville	6.62	Chapel Hill	0.54
North Dakota	68.4	+5.9	2 stations	110	[1] 16	Hansboro	27	7	2.35	−1.10	McLeod	9.27	Powers Lake	0.11
Ohio	70.8	+1.7	4 stations	101	[1] 20	2 stations	35	2	3.58	−0.25	Kings Mills	6.99	Gallipolis	1.33
Oklahoma	79.7	+2.5	Goodwell	106	20	Smithville	41	1	2.01	−1.97	Cleveland	6.82	Walters	0.18
Oregon	60.0	+0.6	Umatilla	107	7	Seneca	16	30	2.31	+0.97	Astoria	7.70	Vale	0.23
Pennsylvania	68.5	+0.6	3 stations	102	[1] 20	Ridgway	28	2	3.71	−0.47	Natrona	8.08	Greenville	1.23
South Carolina	77.8	+0.4	Laurens	106	29	Walhalla	43	9	2.21	−2.57	Beaufort (near)	6.09	Aiken	0.11
South Dakota	74.4	+8.6	LaDelle	115	28	2 stations	35	[1] 5	2.37	−1.12	Ipswich	9.62	Vale	0.18
Tennessee	76.8	+2.3	2 stations	106	29	Crossville	34	9	1.86	−2.46	Covington	5.30	Parksville	0.08
Texas	80.6	+0.4	Fort Stockton	109	19	Alpine	46	2	2.01	−1.19	Runge	12.58	2 stations	0.00
Utah	68.1	+3.3	2 stations	104	[1] 24	Panguitch	29	2	0.25	−0.35	Monticello	1.34	3 stations	0.00
Virginia	72.3	+0.8	Lincoln	103	30	Burkes Garden	34	2	3.23	−1.06	Chatham	6.36	Quantico	0.70
Washington	60.3	−0.3	Wahluke	107	7	Paradise Inn	26	2	3.66	+2.16	Big Four	16.39	Hanford	0.51
West Virginia	69.8	+1.0	Charleston	105	20	Bayard	33	2	3.24	−1.38	Horton	7.18	Piedmont	1.12
Wisconsin	69.1	+4.6	Plum Island	106	30	Coddington	24	8	4.55	+0.51	Park Falls	10.84	Sturgeon Bay	1.56
Wyoming	63.0	+4.8	2 stations	105	28	Bedford	22	18	1.04	−0.54	Sundance	3.80	Thermopolis	0.00
Alaska [May]	39.8	−3.0	Tree Point	78	21	Eagle	2	[1] 3	2.08	+0.74	Yakutat	17.11	Barrow	T.
Hawaii	74.5	+1.3	Kaanapali	94	[1] 8	Kanalohuluhulu	45	[1] 9	2.84	−1.93	Puu Kukui (upper)	19.00	8 stations	0.00
Porto Rico	79.5	+1.1	Mayaguez	96	10	Guineo Reservoir	49	28	10.51	+4.27	San Lorenzo	25.11	Barceloneta	2.64

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							**64.4**	**+0.8**										**77**	**5.10**	**+2.1**										**5.4**		
Eastport	76	67	85	29.85	29.93	0.00	57.0	+1.9	86	20	65	45	7	49	32	53	51	83	3.56	+0.6	15	6,717	nw.	40	e.	10	2	11	17	7.5	0.0	0.0
Greenville, Me	1,070	6	----	28.81	29.96	----	60.4	----	86	19	70	40	3	51	36	55	----	77	4.75	----	14	3,868	nw.	23	----	21	10	7	13	----	0.0	0.0
Portland, Me	103	82	117	29.82	29.94	−.01	64.2	+1.7	94	20	72	50	10	56	31	57	52	68	5.40	+2.1	14	5,475	n.	27	ne.	9	13	9	8	4.7	0.0	0.0
Concord	289	70	79	29.63	29.94	−.02	65.6	+2.7	94	20	77	44	25	55	35	----	----	----	5.35	+2.2	14	3,290	n.	20	nw.	26	15	6	9	4.6	0.0	0.0
Burlington	403	11	48	29.53	29.96	.00	63.4	−2.3	92	20	74	43	24	53	34	----	----	----	2.46	−0.9	13	4,577	n.	24	s.	8	9	10	11	5.5	0.0	0.0
Northfield	876	12	60	29.04	29.98	+.02	60.6	−0.7	90	30	73	38	24	48	40	59	57	84	4.00	+0.8	11	3,741	s.	19	n.	27	9	13	8	5.3	0.0	0.0
Boston	125	106	165	29.81	29.94	−.02	67.2	+0.7	97	20	75	48	10	59	26	60	55	68	9.13	+6.2	12	4,896	nw.	24	n.	5	9	12	9	5.6	0.0	0.0
Nantucket	12	14	90	29.91	29.92	−.06	62.0	+1.0	83	21	68	51	7	56	21	58	56	84	6.55	+3.9	10	9,386	n.	36	ne.	10	11	9	10	5.4	0.0	0.0
Block Island	26	11	46	29.90	29.93	−.04	63.5	+1.7	83	30	69	53	10	58	22	59	58	87	4.57	+2.0	8	8,872	sw.	36	ne.	10	12	7	11	5.3	0.0	0.0
Providence	160	215	251	29.77	29.93	−.04	67.3	−1.0	93	20	76	51	10	58	29	61	57	73	4.95	+2.3	12	6,862	nw.	28	nw.	21	16	3	11	4.8	0.0	0.0
Hartford	159	122	----	29.77	29.94	−.03	68.4	+1.3	94	20	78	52	10	59	33	----	----	----	4.75	+1.7	12	----	s.	----	----	----	13	8	9	5.1	0.0	0.0
New Haven	106	74	153	29.83	29.94	−.03	68.7	+2.1	96	20	77	53	10	60	31	62	58	73	5.33	+2.2	11	5,742	n.	24	nw.	21	10	10	10	5.5	0.0	0.0
Middle Atlantic States							**70.9**	**+0.6**										**70**	**3.20**	**−0.4**										**4.9**		
Albany	97	107	115	29.85	29.95	−.02	68.6	+0.6	95	20	78	52	4	59	31	61	56	68	4.00	+0.6	12	4,502	s.	22	n.	1	17	4	9	4.1	0.0	0.0
Binghamton	871	10	84	29.08	30.00	+.03	66.4	+0.8	94	30	78	44	2	55	36	----	----	----	1.75	−1.6	8	3,184	nw.	18	n.	17	7	11	12	6.1	0.0	0.0
New York	314	414	454	29.62	29.94	−.04	69.4	+0.6	93	20	77	54	9	62	24	61	56	68	4.00	+0.7	11	8,801	n.	42	nw.	7	9	10	11	5.9	0.0	0.0
Bellefonte	1,050	5	36	28.89	29.98	----	66.0	----	94	20	79	38	2	53	42	60	57	73	1.78	----	7	----	sw.	----	----	----	8	10	12	5.9	0.0	0.0
Harrisburg	374	94	104	29.60	29.99	.00	71.0	+0.7	98	20	81	52	2	61	32	62	56	62	3.28	−0.3	8	3,865	ne.	29	w.	7	11	11	8	4.8	0.0	0.0
Philadelphia	114	123	367	29.86	29.98	.00	72.9	+1.5	98	20	81	57	9	64	28	63	57	62	3.75	+0.5	10	8,099	n.	34	s.	7	9	13	8	5.2	0.0	0.0
Reading	325	81	98	29.63	29.77	----	71.0	+1.2	98	20	81	51	2	61	29	62	56	61	4.86	+1.3	9	3,496	n.	16	n.	9	11	11	8	5.0	0.0	0.0
Scranton	805	111	119	29.14	29.99	+.01	68.0	+0.2	95	20	79	47	3	57	36	61	56	69	3.04	−0.6	9	4,022	n.	33	nw.	20	11	11	8	5.1	0.0	0.0
Atlantic City	52	37	172	29.91	29.96	−.02	68.4	+1.8	94	30	75	56	9	62	25	63	60	79	2.54	−0.5	8	9,153	s.	34	s.	7	12	11	7	4.8	0.0	0.0
Cape May	17	13	49	----	----	----	68.5	+0.8	89	30	76	56	2	61	23	64	61	80	2.50	−0.5	8	----	se.	----	----	----	4	17	9	----	0.0	0.0
Sandy Hook	22	10	55	29.92	29.94	----	68.8	----	90	20	76	54	10	62	24	63	60	78	3.66	−0.1	9	7,518	sw.	35	nw.	7	15	9	6	4.1	0.0	0.0
Trenton	190	159	183	29.76	29.96	----	70.4	+0.9	95	20	80	54	3	61	31	63	59	72	4.28	+1.2	14	5,724	n.	41	nw.	7	8	13	9	5.5	0.0	0.0
Baltimore	123	100	215	29.84	29.97	−.02	74.5	+1.8	100	20	83	56	2	66	27	64	59	62	1.89	−2.0	9	6,436	sw.	30	sw.	7	12	11	7	5.1	0.0	0.0
Washington	112	62	85	29.86	29.98	−.02	73.3	+1.1	99	20	83	52	3	64	31	64	59	66	2.12	−2.0	10	3,473	nw.	27	n.	26	12	12	6	4.3	0.0	0.0
Cape Henry	18	8	54	29.96	29.98	----	72.0	−0.9	93	20	79	56	3	65	27	66	64	77	3.43	−0.5	9	6,672	sw.	31	n.	1	12	12	6	4.5	0.0	0.0
Lynchburg	681	153	188	29.26	29.99	−.02	74.5	−0.1	98	20	86	52	2	64	32	66	63	70	2.43	−1.4	7	3,503	n.	33	nw.	22	14	12	4	4.1	0.0	0.0
Norfolk	91	170	205	29.90	30.00	.00	73.8	−0.6	92	21	83	58	2	65	26	65	62	72	5.13	+0.9	8	6,812	s.	43	w.	23	13	10	7	4.5	0.0	0.0
Richmond	144	11	52	29.84	29.99	−.02	73.8	−0.3	95	21	84	51	2	63	30	66	63	72	2.98	−0.9	8	4,138	sw.	28	sw.	7	13	11	6	4.1	0.0	0.0
Wytheville	2,304	49	55	27.69	30.00	−.01	68.6	−0.1	92	20	81	41	2	56	37	61	57	71	2.05	−2.2	7	2,826	w.	24	ne	21	10	13	7	5.0	0.0	0.0
South Atlantic States							**77.3**	**+0.9**										**69**	**2.20**	**−2.4**										**4.2**		
Asheville	2,253	89	104	27.74	30.02	+.01	71.8	+3.1	95	28	84	45	2	59	35	63	59	71	3.44	−0.5	9	3,375	nw.	23	n.	15	13	15	2	3.6	0.0	0.0
Charlotte	779	55	62	29.19	30.01	.00	77.8	+2.3	98	23	89	53	9	66	30	67	61	61	0.60	−3.6	6	2,425	s.	15	w.	7	11	13	6	4.5	0.0	0.0
Greensboro	886	6	56	29.08	30.02	----	74.0	----	98	21	87	46	9	61	34	66	62	70	2.27	----	9	4,424	sw.	41	nw.	21	8	16	6	5.2	0.0	0.0
Hatteras	11	5	50	29.99	30.00	−.01	72.7	−2.9	86	24	80	57	3	66	22	68	66	81	3.82	−0.7	4	7,386	sw.	44	w.	8	19	8	3	3.0	0.0	0.0
Raleigh	376	103	146	29.61	29.99	−.02	76.4	+0.7	96	27	87	53	2	66	28	67	62	64	2.53	−1.9	5	4,691	sw.	33	nw.	5	6	21	3	4.9	0.0	0.0
Wilmington	78	81	91	29.95	30.03	+.02	75.8	−1.0	93	24	84	56	9	67	25	69	65	74	1.82	−3.3	8	4,222	sw.	19	s.	7	19	8	3	3.5	0.0	0.0
Charleston	48	11	92	29.97	30.02	+.01	78.4	−0.5	97	28	85	63	9	72	21	71	68	75	2.46	−2.1	7	6,452	sw.	35	sw.	7	11	14	5	4.3	0.0	0.0
Columbia, S. C	351	41	57	29.64	30.01	.00	79.2	+1.1	101	28	91	55	9	68	31	67	62	61	1.85	−2.3	5	3,799	s.	28	sw.	7	17	10	3	3.9	0.0	0.0
Due West	711	10	55	29.28	30.04	----	78.8	----	103	29	91	54	9	66	32	----	----	----	2.39	----	9	4,547	s.	32	n.	29	12	11	7	4.8	0.0	0.0
Greenville, S. C	1,039	139	146	28.93	30.00	----	78.6	+4.5	101	29	89	56	9	68	27	66	60	60	0.78	−3.8	5	4,135	ne.	32	sw.	7	12	14	4	4.3	0.0	0.0
Augusta	182	62	77	29.80	29.99	−.02	80.9	+2.2	105	28	93	57	9	69	30	70	65	65	1.29	−3.4	10	3,352	s.	30	n.	6	12	14	4	4.0	0.0	0.0
Savannah	65	150	194	29.94	30.01	.00	79.6	+0.6	98	29	90	60	9	70	30	71	68	74	2.68	−2.6	8	6,589	s.	42	n.	24	18	5	7	3.9	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	+.01	79.6	−0.3	98	29	88	61	9	71	26	71	67	72	2.97	−2.4	7	6,449	s.	32	sw.	6	12	15	3	4.4	0.0	0.0
Florida Peninsula							**81.2**	**+0.5**										**74**	**1.17**	**−5.0**										**5.1**		
Key West	22	10	64	29.97	29.99	.00	81.7	−0.2	91	16	87	71	22	76	14	75	73	75	1.96	−2.3	7	5,783	e.	31	se.	22	12	12	6	4.8	0.0	0.0
Miami	25	124	168	29.99	30.02	+.01	80.5	+0.5	90	9	86	69	1	76	17	74	71	73	0.07	−6.8	5	5,801	e.	19	s.	1	4	14	12	6.4	0.0	0.0
Tampa	35	79	197	29.98	30.01	.00	81.3	+1.1	95	28	91	65	5	72	27	72	69	73	1.47	−5.8	7	6,073	e.	32	se.	21	6	20	4	5.7	0.0	0.0
Titusville	44	5	----	29.97	30.03	----	80.7	----	96	30	91	64	6	71	28	----	----	----	1.38	----	3	----	se.	----	----	----	15	13	2	3.6	0.0	0.0
East Gulf States							**80.2**	**+1.7**										**64**	**1.82**	**−2.9**										**4.0**		
Atlanta	1,173	190	198	28.80	30.01	.00	79.3	+3.3	101	29	90	53	9	69	29	65	58	54	0.39	−3.4	4	5,002	w.	33	w.	30	17	13	0	4.0	0.0	0.0
Macon	370	78	87	29.61	30.00	−.01	81.2	+2.3	104	28	94	53	9	69	35	68	61	55	0.79	−3.2	5	3,450	s.	20	sw.	7	11	14	5	4.4	0.0	0.0
Thomasville	273	49	103	29.72	30.01	+.01	81.2	+1.7	103	29	93	58	10	69	34	69	64	63	2.06	−3.4	4	4,129	sw.	30	ne.	29	12	16	2	4.1	0.0	0.0
Apalachicola	36	11	51	29.98	30.02	----	79.2	----	96	29	87	62	9	72	23	73	70	75	3.15	−2.4	5	4,694	w.	36	e.	25	20	10	0	2.4	0.0	0.0
Pensacola	56	149	185	29.96	30.02	+.03	79.0	−0.3	93	25	85	64	1	73	19	71	68	72	1.53	−3.2	3	6,760	sw.	36	e.	25	9	16	5	4 8	0 0	0 0
Anniston	741	9	57	----	----	----	78 4	+3 4	104	28	93	46	9	64	40	----	----	----	2.03	----	5	2,150	se.	15	ne.	19	17	9	4	----	0.0	0.0
Birmingham	700	11	48	29.27	30.02	+.03	80.8	+2.9	106	29	94	52	2	68	33	67	61	59	0.47	−4.0	4	2,788	n.	21	se.	25	17	10	3	3.3	0.0	0.0
Mobile	57	125	161	29.96	30.02	+.03	80.4	+0.1	98	29	90	60	2	71	27	71	68	72	0.65	−4.8	5	4,798	sw.	25	w.	16	10	14	6	4.7	0.0	0.0
Montgomery	223	100	112	29.77	30.01	+.01	81.8	+2.2	100	29	93	58	9	71	31	68	62	56	1.61	−2.2	6	3,581	sw.	27	n.	29	10	15	5	4.4	0.0	0.0
Corinth	469	6	----	----	----	----	80.5	----	105	28	94	49	2	67	40	----	----	----	2.31	----	7	----	se.	----	----	----	15	14	1	----	0.0	0.0
Meridian	375	87	95	29.63	30.01	+.03	79.2	+1.1	101	30	92	53	2	67	35	68	63	62	3.47	−1.1	4	2,762	sw.	25	w.	13	14	13	3	4.0	0.0	0.0
Vicksburg	247	65	73	29.76	30.04	+.07	79.8	+0.8	97	29	90	60	1	69	28	70	66	68	3.30	−0.7	7	3,365	s.	29	sw.	30	18	12	0	3.0	0.0	0.0
New Orleans	53	76	84	29.96	30.01	+.03	81.3	+0.7	95	29	89	68	5	73	20	72	69	70	2.56	+3.3	10	3,185	se.	30	se.	30	9	17	4	4.7	0.0	0.0
West Gulf States							**80.4**	**+0.9**										**71**	**2.26**	**−1.0**										**4.1**		
Shreveport	249	77	93	29.73	29.99	+.03	81.6	+0.9	100	30	92	61	1	71	25	71	66	66	1.28	−2.2	5	3,334	s.	22	sw.	13	19	7	4	3.4	0.0	0.0
Bentonville	1,303	11	44	28.59	29.95	+.01	75.8	+1.7	95	28	86	45	1	65	31	----	----	----	3.01	----	7	2,636	s.	17	s.	11	27	3	0	----	0.0	0.0
Fort Smith	457	79	94	29.48	29.95	+.01	79.7	+2.2	100	30	90	54	1	69	29	70	66	65	1.57	−2.2	7	4,081	e.	32	n.	6	14	14	2	3.9	0.0	0.0
Little Rock	357	136	153	29.62	29.99	+.03	80.1	+2.7	102	30	90	57	1	70	26	69	64	63	2.76	−1.0	8	4,549	sw.	30	nw.	6	17	5	8	4.5	0.0	0.0
Austin	605	136	148	29.33	29.96	----	82.0	+0.8	97	16	93	55	1	71	32	72	68	70	2.63	+0.2	9	4,834	se.	35	s.	21	8	18	4	5.0	0.0	0.0
Brownsville	57	83	100	29.88	29.94	----	81.1	−1.3	92	16	88	68	26	74	17	74	73	81	1.02	−1.8	5	6,936	se.	27	ne.	26	9	18	3	4.5	0.0	0.0
Corpus Christi	20	11	78	29.95	29.97	+.06	81.0	0.0	93	16	86	66	1	76	18	75	74	84	8.36	+5.8	4	8,248	se.	36	ne.	27	10	16	4	4.4	0.0	0.0
Dallas	512	220	227	29.42	29.96	----	81.2	----	97	26	91	62	1	72	27	----	----	----	0.94	−3.0	5	7,190	se.	44	ne.	12	14	13	3	3.2	0.0	0.0
Fort Worth	670	106	114	29.24	29.94	+.02	81.4	+1.5	98	26	92	57	1	71	29	70	65	61	2.43	−0.9	8	6,023	se.	29	e.	12	13	13	4	4.6	0.0	0.0
Galveston	54	106	114	29.96	30.02	+.07	80.5	−0.2	89	25	84	71	1	77	14	74	72	79	1.74	−2.6	1	6,930	se.	30	w.	26	13	14	3	3.6	0.0	0.0
Houston	138	292	314	29.85	29.99	----	81.6	+0.2	97	16	90	64	1	73	23	----	----	----	0.61	−4.0	4	7,059	se.	33	se.	26	12	16	2	4.1	0.0	0.0
Palestine	510	64	72	29.46	29.98	+.04	80.8	+1.8	96	25	91	61	1	71	27	71	67	68	0.97	−2.7	5	4,510	s.	25	nw.	16	12	13	5	4.3	0.0	0.0
Port Arthur	34	58	66	29.97	30.01	----	81.5	----	94	25	88	64	1	74	20	74	71	75	0.88	----	3	4,588	s.	20	e.	26	20	8	2	3.0	0.0	0.0
San Antonio	693	242	301	29.23	29.94	+.04	81.2	+0.2	96	13	91	63	1	71	24	71	66	67	3.10	+0.6	7	7,171	e.	40	ne.	26	8	18	4	4.7	0.0	0.0
Taylor	571	38	51	29.40	30.00	+.08	81.6	+1.6	98	16	93	55	1	70	34	----	----	----	2.74	+0.7	6	5,290	s.	25	nw.	16	18	11	1	3.7	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							74.8	+2.0										65	3.13	−0.8										5.0		
Chattanooga	762	190	215	29.20	29.99	−0.01	78.6	+3.2	101	28	91	52	9	66	34	65	58	54	0.29	−3.9	4	4,045	sw.	29	ne.	25	13	13	4	4.4	0.0	0.0
Knoxville	995	102	111	28.98	30.01	+.01	77.2	+3.2	101	27	90	50	9	65	33	65	59	59	1.50	−2.6	6	3,367	n.	27	sw.	7	9	19	2	4.6	0.0	0.0
Memphis	399	76	97	29.58	29.99	+.02	80.6	+3.0	101	29	90	56	1	71	26	68	62	58	1.09	−2.5	7	4,347	sw.	40	sw.	7	16	11	3	3.7	0.0	0.0
Nashville	546	168	191	29.46	30.03	+.04	77.7	+2.1	100	29	89	51	9	66	32	67	62	63	2.31	−1.7	7	4,461	nw.	48	n.	15	12	14	4	4.2	0.0	0.0
Lexington	989	193	230	29.00	30.04	+.04	74.8	+2.6	96	28	85	49	1	65	29	----	----	----	1.83	−2.2	9	6,548	sw.	39	nw.	20	12	16	2	3.8	0.0	0.0
Louisville	525	188	234	29.45	30.02	+.04	76.0	+1.3	99	28	86	50	1	66	27	67	63	68	3.14	−0.7	10	4,790	s.	63	nw.	29	6	16	8	5.4	0.0	0.0
Evansville	431	76	116	29.54	30.00	+.03	77.9	+2.8	101	29	88	49	1	67	25	68	64	65	3.55	−0.5	10	4,499	s.	39	sw.	12	11	18	1	4.3	0.0	0.0
Indianapolis	822	194	230	29.12	29.99	+.02	75.0	+3.4	98	28	85	47	1	66	24	65	59	61	2.20	−1.4	9	5,651	s.	34	w.	7	9	10	11	5.7	0.0	0.0
Royal Center	736	11	55	29.20	29.99	------	72.2	------	96	28	83	41	1	62	30	----	----	----	8.97	+5.4	10	5,004	s.	30	e.	29	8	6	16	6.1	0.0	0.0
Terre Haute	575	96	129	29.38	29.98	------	75.8	------	101	28	86	44	1	65	30	67	62	67	3.74	−0.2	10	4,589	s.	42	n.	22	12	6	12	5.4	0.0	0.0
Cincinnati	627	11	51	29.35	30.01	+.02	73.9	+2.7	99	27	85	46	9	63	33	66	61	69	3.30	−0.4	13	3,027	sw.	26	nw.	7	8	12	10	5.6	0.0	0.0
Columbus	822	216	230	29.15	30.01	+.02	72.5	+1.6	95	28	82	46	1	63	29	63	58	64	2.30	−1.0	7	5,097	s.	43	w.	7	6	15	9	5.6	0.0	0.0
Dayton	899	137	173	29.06	30.00	------	74.0	+2.6	98	28	84	46	9	64	28	64	59	63	2.90	−0.9	11	4,011	sw.	35	sw.	6	5	21	4	5.5	0.0	0.0
Elkins	1,947	59	67	28.03	30.04	+.04	66.4	−0.5	92	20	79	39	10	54	39	60	57	78	3.09	−2.0	13	2,452	nw.	31	nw.	26	10	10	10	5.5	0.0	0.0
Parkersburg	637	77	82	29.38	30.03	+.03	72.5	+1.1	97	20	84	46	10	61	35	64	59	68	4.18	+0.2	11	2,536	nw.	30	n.	26	8	12	10	5.8	0.0	0.0
Pittsburgh	842	353	410	29.12	30.00	+.01	70.0	−0.7	93	20	81	47	2	59	29	64	61	75	5.72	+1.9	10	4,740	n.	45	w.	20	7	16	7	5.2	0.0	0.0
Lower Lake Region							67.6	+0.9										69	2.63	−0.7										4.9		
Buffalo	767	247	280	29.17	29.99	+.02	65.9	+1.5	90	29	74	47	9	58	30	58	54	70	2.46	−0.4	8	7,712	sw.	42	nw.	25	13	10	7	4.6	0.0	0.0
Canton	448	10	61	29.49	29.95	------	63.8	−2.0	90	30	75	41	22	52	32	----	----	----	2.67	−0.6	12	4,435	sw.	24	sw.	19	10	11	9	5.1	0.0	0.0
Ithaca	836	74	100	29.09	29.98	------	65.8	−0.4	98	30	78	42	2	54	41	59	55	68	1.75	−1.8	10	4,913	nw.	29	sw.	20	9	14	7	5.6	0.0	0.0
Oswego	335	71	85	29.61	29.98	+.01	63.5	−1.3	93	20	72	47	2	55	30	58	54	71	2.16	−1.1	10	4,500	w.	18	sw.	20	9	10	11	5.4	0.0	0.0
Rochester	523	86	102	29.44	30.00	+.03	67.3	+1.2	93	20	77	48	2	58	29	59	54	64	2.35	−0.6	8	4,526	sw.	22	sw.	19	12	12	6	4.4	0.0	0.0
Syracuse	596	65	79	29.36	30.00	+.03	66.8	−0.1	96	20	77	45	2	57	33	----	----	----	1.15	−2.7	9	4,011	nw.	23	w.	20	14	10	6	4.2	0.0	0.0
Erie	714	130	166	29.24	30.00	+.02	67.8	+1.6	92	20	76	46	2	60	28	62	59	75	1.76	−1.6	8	6,072	nw.	34	nw.	6	15	10	5	4.0	0.0	0.0
Cleveland	762	267	337	29.19	30.00	+.02	68.6	+1.5	93	25	76	50	1	61	29	61	56	67	3.51	+0.4	8	6,350	n.	56	n.	26	9	13	8	5.4	0.0	0.0
Sandusky	629	5	67	29.34	30.01	+.03	69.8	+1.0	96	25	79	45	2	60	34	----	----	----	3.59	+0.1	11	4,125	e.	32	nw.	20	6	15	9	6.0	0.0	0.0
Toledo	628	208	243	29.33	30.00	+.03	70.4	+1.7	98	25	79	47	1	62	32	62	58	67	4.85	+1.5	11	6,682	e.	35	w.	20	9	14	7	4.6	0.0	0.0
Fort Wayne	856	100	119	29.09	30.00	------	72.1	+3.6	95	28	82	45	9	62	28	64	60	69	3.04	−0.5	9	5,033	sw.	33	sw.	6	8	15	7	5.2	0.0	0.0
Detroit	730	218	258	29.23	30.02	+.05	69.6	+2.2	98	25	79	46	1	60	34	61	56	67	2.27	−1.3	9	5,168	sw.	35	sw.	20	11	14	5	4.5	0.0	0.0
Upper Lake Region							65.5	+3.1										73	3.19	0.0										5.7		
Alpena	609	13	92	29.34	30.01	+.05	61.6	+1.2	99	30	70	38	1	53	32	57	53	75	2.90	−0.4	11	6,265	se.	45	nw.	19	6	16	8	5.5	0.0	0.0
Escanaba	612	54	60	29.31	29.97	+.03	62.6	+1.9	95	19	70	41	8	55	30	57	54	75	2.63	−0.6	7	6,004	s.	26	n.	7	9	13	8	5.1	0.0	0.0
Grand Haven	632	54	89	29.30	29.97	+.01	67.2	+3.5	89	27	76	40	9	59	26	61	57	71	1.75	−1.2	10	6,288	se.	28	ne.	26	7	9	14	6.4	0.0	0.0
Grand Rapids	707	70	244	29.23	29.98	+.01	71.2	+3.4	99	30	82	43	1	61	29	63	58	65	2.49	−1.0	8	6,438	se.	38	n.	26	6	11	13	6.5	0.0	0.0
Houghton	668	64	99	29.23	29.95	+.01	62.6	+2.6	102	30	73	40	1	52	35	----	----	----	1.81	−1.1	15	5,809	e.	40	w.	19	9	9	12	5.9	0.0	0.0
Lansing	878	6	88	29.06	29.98	------	68.0	+1.6	95	25	78	41	9	58	33	63	60	78	3.73	+0.2	12	4,437	s.	32	nw.	26	4	19	7	5.6	0.0	0.0
Ludington	637	60	66	29.28	29.98	------	65.2	+4.7	87	12	72	41	1	58	26	60	57	76	3.52	+0.6	12	5,482	s.	30	n.	26	13	11	6	4.5	0.0	0.0
Marquette	734	77	111	29.16	29.96	+.02	62.6	+3.7	101	29	72	44	16	53	39	57	52	70	4.12	+0.9	11	5,189	s.	33	sw.	9	5	13	12	6.4	0.0	0.0
Port Huron	638	70	120	29.31	30.00	+.03	65.0	+0.8	96	30	74	40	1	56	31	59	55	71	2.27	−0.5	10	5,732	s.	45	w.	20	7	12	11	5.8	0.0	0.0
Sault Sainte Marie	614	11	52	29.31	30.00	+.04	61.6	+3.0	90	30	72	37	1	52	33	56	51	73	3.45	+0.5	12	4,337	se.	24	nw.	8	11	11	8	5.0	0.0	0.0
Chicago	673	7	131	29.26	29.98	+.02	71.8	+4.5	98	28	79	48	1	64	27	64	60	70	4.78	+1.5	8	5,706	s.	30	nw.	22	12	5	13	5.5	0.0	0.0
Green Bay	617	109	141	29.29	29.95	.00	69.2	+4.3	100	30	78	44	8	60	28	62	58	71	3.17	−0.5	11	6,241	s.	27	nw.	26	6	7	17	6.7	0.0	0.0
Milwaukee	681	125	221	29.24	29.96	+.01	69.0	+5.1	100	30	78	46	8	60	32	60	57	70	3.58	+0.2	11	7,333	se.	27	n.	22	8	13	9	5.7	0.0	0.0
Duluth	1,133	5	47	28.76	29.96	+.04	60.0	+2.8	94	29	70	41	1	50	42	55	51	79	4.57	+0.7	12	6,948	ne.	41	w.	19	10	8	12	5.8	0.0	0.0
North Dakota							68.7	+5.5										58	2.39	−1.4										5.3		
Moorhead	910	50	58	28.85	29.85	−.05	69.0	+4.6	102	30	80	37	7	58	34	61	56	64	2.79	−1.3	12	5,090	s.	24	e.	21	7	14	9	5.7	0.0	0.0
Bismarck	1,674	8	57	28.09	29.83	−.04	69.6	+5.9	104	28	82	43	5	58	35	59	52	59	1.66	−1.7	9	5,959	e.	34	e.	21	12	12	6	4.7	0.0	0.0
Devils Lake	1,478	11	44	28.30	29.85	−.03	66.8	+4.9	98	17	79	36	7	54	36	58	51	61	2.54	−1.0	12	6,066	ne.	31	nw.	27	8	12	10	5.8	0.0	0.0
Ellendale	1,457	10	56	28.24	29.84	------	68.8	------	102	28	81	40	7	57	36	----	----	----	3.72	−0.9	10	8,206	ne.	48	nw.	21	7	15	8	5.6	0.0	0.0
Grand Forks	833	12	67	------	------	------	67.8	------	99	30	80	32	7	56	37	60	----	----	2.81	------	13	------	se.	----	------	----	11	13	6	----	0.0	0.0
Williston	1,878	41	48	27.89	29.82	−.04	69.3	+6.6	108	16	82	44	7	57	43	56	46	50	1.24	−2.2	7	5,458	se.	37	w.	28	14	10	6	4.5	0.0	0.0
Upper Mississippi Valley							75.8	+5.3										66	3.96	−0.1										4.9		
Minneapolis	918	102	208	28.90	29.86	------	73.7	+6.2	102	29	84	47	7	64	28	----	----	----	4.78	+0.6	12	7,013	s.	44	nw.	19	7	11	12	6.2	0.0	0.0
St. Paul	837	114	149	29.00	29.89	−.03	73.4	+6.3	101	29	84	47	8	63	34	----	----	----	4.07	−0.1	12	5,445	sw.	43	nw.	19	8	16	6	5.6	0.0	0.0
La Crosse	714	11	48	29.16	29.91	−.02	73.8	+5.5	101	29	84	42	8	63	28	66	62	72	4.49	+0.4	10	2,598	s.	15	nw.	19	8	12	10	5.7	0.0	0.0
Madison	974	70	78	28.92	29.94	.00	71.4	+4.2	99	30	80	46	8	62	29	64	60	70	3.05	−0.7	10	4,674	s.	40	ne.	15	11	8	11	5.2	0.0	0.0
Wausau	1,247	4	62	28.64	29.95	------	68.8	------	100	29	80	39	8	58	31	----	----	----	6.34	+2.3	14	3,645	s.	25	se.	3	9	11	10	5.8	0.0	0.0
Charles City	1,015	10	51	28.87	29.91	.00	74.5	+8.0	102	28	86	42	8	63	33	66	62	68	2.41	−2.2	9	4,315	se.	24	nw.	19	14	10	6	4.0	0.0	0.0
Davenport	606	71	79	29.29	29.94	.00	76.5	+6.0	104	30	86	46	8	67	26	66	61	62	2.21	−1.9	6	5,745	sw.	34	sw.	11	12	10	8	4.8	0.0	0.0
Des Moines	861	51	99	29.02	29.90	−.02	76.4	+5.8	99	23	86	46	8	67	30	68	64	67	6.14	+1.4	10	6,010	s.	36	nw.	19	15	9	6	4.6	0.0	0.0
Dubuque	700	81	96	29.20	29.93	.00	75.1	+5.7	103	28	85	45	8	65	31	66	62	67	2.31	−2.0	9	3,648	s.	21	n.	22	12	6	12	5.2	0.0	0.0
Keokuk	614	64	78	29.30	29.96	+.02	76.5	+4.0	102	30	86	48	8	67	24	68	64	67	6.56	+2.4	10	3,911	sw	24	nw.	7	13	8	9	4.2	0.0	0.0
Cairo	358	87	93	29.61	29.98	+.01	79.2	+2.9	100	29	89	54	1	69	25	69	64	64	3.13	−0.7	8	3,903	s.	34	n.	7	7	13	10	5.7	0.0	0.0
Peoria	609	11	45	29.32	29.98	+.03	75.7	+4.8	103	29	86	44	8	65	28	67	63	68	2.29	−1.5	10	3,088	sw.	19	ne.	5	14	11	5	3.8	0.0	0.0
Springfield, Ill.	636	5	191	29.30	29.96	+.01	77.4	+5.2	102	30	88	48	8	67	29	67	62	62	3.94	−0.1	11	7,123	s.	36	nw.	7	10	10	10	5.2	0.0	0.0
Hannibal	534	74	109	29.40	29.97	+.02	77.6	+5.1	102	30	87	49	8	68	28	----	----	----	5.72	+1.8	8	4,575	sw.	26	nw.	11	13	11	6	4.1	0.0	0.0
St. Louis	568	265	303	29.37	29.97	+.02	79.6	+4.8	102	29	89	54	1	70	26	68	63	60	1.98	−1.8	6	7,061	s.	39	n.	4	16	13	1	3.5	0.0	0.0
Missouri Valley							77.5	+6.7										60	2.32	−2.0										3.6		
Columbia, Mo.	784	6	84	29.14	29.95	.00	78.0	+5.2	101	30	88	49	8	68	29	----	----	----	1.30	−3.5	7	4,011	s.	23	nw.	7	15	9	6	4.0	0.0	0.0
Kansas City	963	161	181	28.91	29.91	−.01	79.7	+6.1	101	27	89	57	7	70	25	68	62	58	1.50	−3.5	4	4,963	s.	35	sw.	5	19	9	2	3.0	0.0	0.0
St. Joseph	967	11	49	28.90	29.90	------	78.7	------	100	30	89	53	8	68	33	68	64	63	2.42	−2.5	6	4,961	sw.	38	nw.	20	19	8	3	2.6	0.0	0.0
Springfield, Mo.	1,324	98	104	28.61	29.98	+.03	76.4	+3.9	97	30	86	52	1	67	28	67	61	62	0.84	−3.8	5	5,931	s.	26	se.	11	27	3	0	1.2	0.0	0.0
Iola	984	11	50	28.91	29.93	−.00	77.8	+3.7	99	27	89	52	1	67	29	----	----	----	3.10	−2.4	5	3,686	s.	17	sw.	10	21	5	4	3.2	0.0	0.0
Topeka	987	92	107	------	------	------	78.2	+4.8	98	28	89	55	1	68	26	----	----	----	2.85	−1.8	4	6,186	sw.	30	ne.	20	18	6	6	3.0	0.0	0.0
Lincoln	1,189	11	81	28.63	29.86	−.04	78.4	+7.0	101	27	89	51	7	67	31	68	63	64	4.42	+0.1	8	6,587	s.	34	n.	20	12	12	6	4.6	0.0	0.0
Omaha	1,105	115	122	28.73	29.88	−.03	79.0	+7.4	102	28	89	51	7	69	30	67	62	61	4.96	+0.4	8	4,565	s.	38	nw.	20	18	6	6	3.3	0.0	0.0
Valentine	2,598	47	54	27.20	29.85	−.01	75.4	+8.5	104	27	89	45	7	62	41	62	55	56	1.31	−1.6	6	6,657	sw.	32	sw.	17	9	14	7	4.8	0.0	0.0
Sioux City	1,135	94	164	28.67	29.84	−.06	77.2	+7.7	102	28	88	46	7	67	31	66	61	62	2.90	−1.1	11	7,892	s.	44	nw.	19	11	9	10	5.1	0.0	0.0
Huron	1,306	59	74	28.48	29.84	−.04	74.6	+8.4	108	28	88	44	7	62	46	63	57	59	1.51	−2.3	10	6,238	s.	27	nw.	14	15	12	3	4.0	0.0	0.0
Pierre	1,572	70	75	28.18	29.80	−.07	76.9	+8.4	110	28	90	50	7	64	37	63	55	52	1.45	−1.5	7	6,488	se.	34	ne.	10	12	16	2	4.0	0.0	0.0
Yankton	1,233	49	57	28.57	29.85	−.04	78.0	+9.1	105	28	89	47	7	67	34	----	----	----	1.63	−2.1	11	4,942	s.	29	se.	3	14	9	7	4.3	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.
Northern Slope							**67.0**	**+5.5**							
Billings	3,140	5	----	----	----	----	69.4	----	102	16	87	43	25	52	52
Havre	2,505	11	67	27.27	29.86	+0.01	67.4	+5.4	100	26	81	42	5	54	46
Helena	4,124	89	113	25.76	29.87	−.01	63.6	+4.4	94	26	76	41	5	51	46
Kalispell	2,973	48	56	26.88	29.88	−.01	61.0	+3.3	86	7	74	38	30	48	34
Miles City	2,371	48	55	27.36	29.85	.00	72.5	+6.5	107	16	85	45	5	60	41
Rapid City	3,259	50	58	26.53	29.85	.00	72.5	+8.3	105	28	85	50	26	60	39
Cheyenne	6,088	84	101	24.04	29.86	+.02	65.6	+5.2	91	28	79	43	7	52	32
Lander	5,372	60	68	24.63	29.85	.00	66.4	+5.9	92	15	81	41	18	51	42
Sheridan	3,790	10	47	26.03	29.85	----	67.2	----	101	28	83	42	7	52	50
Yellowstone Park	6,241	11	48	----	29.89	+.03	58.1	+2.1	83	25	71	39	12	45	39
Northe Platte	2,821	11	51	26.99	29.83	−.03	75.5	+8.0	101	27	89	48	7	62	37
Middle Slape							**76.7**	**+4.9**							
Denver	5,292	106	113	24.74	29.87	+.03	71.3	+5.0	96	28	84	50	11	59	32
Pueblo	4,685	80	86	25.28	29.84	+.01	74.6	+5.6	98	27	90	49	11	59	38
Concordia	1,392	50	58	28.45	29.88	−.02	79.0	+6.0	100	27	90	55	8	68	33
Dodge City	2,509	88	100	27.36	29.89	+.02	77.4	+4.9	97	26	90	53	1	65	34
Wicbita	1,358	139	158	28.50	29.90	−.01	77.8	+3.4	96	27	88	55	1	68	26
Oklahoma City	1,214	10	47	28.67	29.91	.00	80.6	+4.6	100	27	92	54	1	70	31
Sauthern Slope							**79.5**	**+1.6**							
Abilene	1,738	10	52	28.15	29.91	+.03	82.1	+2.9	99	11	94	58	1	70	32
Amarillo	3,676	10	49	26.26	29.88	+.03	77.8	+5.0	101	19	91	56	10	64	36
Del Rio	944	64	71	28.91	29.87	+.02	80.8	−2.6	96	16	91	58	1	71	27
Roswell	3,566	75	85	26.34	29.85	+.05	77.4	+1.1	101	19	92	55	2	63	42
Southern Plateau							**75.6**	**+1.4**							
El Paso	3,778	152	175	26.14	29.81	+.06	81.8	+2.2	102	20	95	58	3	69	34
Albuquerque	4,972	51	66	25.05	29.79	----	73.3	----	95	26	89	48	10	58	40
Santa Fe	7,013	38	53	23.32	29.82	+.01	67.4	+2.6	89	24	80	41	10	54	35
Flagstaff	6,907	10	59	23.40	29.84	+.06	59.8	+0.5	86	27	76	35	9	44	42
Phoenix	1,108	10	107	28.64	29.76	+.02	87.0	+2.5	110	26	101	62	9	73	38
Yuma	141	9	54	29.63	29.77	+.03	85.5	+0.8	112	27	101	61	17	70	40
Independence	3,957	6	27	25.88	29.84	+.06	71.8	−0.5	97	24	87	47	6	57	40
Middle Plateau							**69.0**	**+3.9**							
Reno	4,532	74	81	25.43	29.85	−.01	63.9	+2.9	91	25	79	35	17	48	44
Tonopah	6,090	12	20	----	----	----	67.0	----	88	24	78	42	17	56	32
Winnemucca	4,344	18	56	25.56	29.87	−.01	67.0	+4.2	93	25	83	39	17	51	43
Modena	5,473	10	43	24.59	29.81	−.01	65.0	+1.7	90	24	82	41	8	48	41
Salt Lake City	4,360	163	203	25.54	29.81	−.04	73.6	+6.2	96	27	86	51	17	62	34
Grand Junction	4,602	60	68	25.33	29.83	.00	75.7	+4.3	97	24	89	53	11	62	36
Northern Plateau							**66.0**	**+2.0**							
Baker	3,471	48	53	26.42	29.97	+.02	59.4	+0.8	91	7	73	35	30	46	43
Boise	2,739	79	87	27.08	29.89	−.02	68.2	+2.9	96	26	82	42	30	54	41
Lewiston	757	40	48	29.12	29.92	−.02	68.6	+2.0	100	7	82	48	30	55	43
Pocatello	4,477	60	68	25.43	29.85	−.02	68.6	+6.4	93	25	82	45	18	55	39
Spokane	1,929	101	110	27.91	29.93	−.01	63.9	+1.1	95	7	75	43	28	53	39
Walla Walla	991	57	65	28.87	29.93	−.03	67.2	+0.7	99	7	78	48	28	56	39
Yakima	1,076	58	67	28.79	29.93	----	66.2	−0.2	100	7	78	44	30	54	35
North Pacific Caast Region							**59.3**	**+0.9**							
Nortb Head	211	11	56	29.80	30.03	+.04	55.8	+1.0	66	5	60	48	4	52	16
Port Angeles	29	8	53	----	30.04	----	55.1	----	80	5	62	42	2	48	33
Seattle	125	215	250	29.86	29.99	−.01	59.6	+0.6	86	6	67	46	2	52	30
Tacoma	194	172	201	29.81	30.01	−.02	60.0	+1.3	85	6	68	47	3	52	30
Tatoosh Island	86	9	53	29.90	30.00	−.02	54.4	+1.4	69	6	58	47	4	50	19
Medford	1,329	29	58	28.57	29.96	----	63.7	----	93	5	77	42	3	51	43
Portland, Oreg	153	68	106	29.84	30.00	−.04	63.6	+1.2	91	6	73	47	3	55	32
Roseburg	510	75	99	29.46	30.01	−.02	62.2	−0.3	92	5	74	42	29	50	43
Middle Pacific Coast Region							**65.9**	**+1.5**							
Eureka	62	73	89	30.00	30.07	+.02	57.3	+3.0	68	15	62	48	12	52	18
Red Bluff	330	5	58	29.53	29.88	.00	75.0	+0.2	101	25	88	55	2	62	35
Sacramento	69	106	117	29.82	29.90	+.01	69.8	+0.4	100	25	83	50	3	56	37
San Francisco	155	208	243	29.80	29.96	.00	62.0	+3.5	84	25	68	52	4	56	24
San Jose	141	12	110	29.83	29.98	----	65.6	+0.6	94	25	77	47	28	54	41
South Pacific Coast Region							**71.0**	**+2.3**							
Fresno	327	89	98	29.54	29.89	+.04	73.8	−2.0	103	25	88	54	3	60	34
Los Angeles	338	159	191	29.56	29.92	+.02	70.5	+4.1	96	25	79	57	3	62	28
San Diego	87	62	70	29.83	29.92	.00	68.7	+4.8	96	24	74	59	6	63	27
West Indies															
San Juan, P. R.	82	9	54	29.90	29.99	----	81.1	+1.4	92	11	86	73	6	76	16
Panama Canal															
Balboa Heights	118	6	97	----	[1]29.84	+.02	80.4	+0.3	91	7	86	73	12	75	18
Cristobal	36	6	97	----	[1]29.84	+.01	82.5	+2.1	91	24	88	76	27	77	15
Alaska															
Fairbanks	455	11	44	[2]29.31	[2]29.82	----	56.6	----	82	17	69	32	3	44	36
Juneau	80	11	50	[2]29.84	[2]29.93	----	54.7	----	77	16	62	39	1	47	30
Hawaiian Islands															
Honolulu	38	86	100	[2]30.02	[2]30.06	----	77.6	+1.0	84	9	82	69	8	73	13

District and station	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date
	°F.	°F.	%	In.	In.		Miles				
Northern Slope			**52**	**1.46**	**−0.9**						
Billings	----	----	----	0.79	----	7	----	nw.	----	----	----
Havre	53	42	47	1.33	−1.5	9	6,353	sw.	50	sw.	27
Helena	50	39	48	1.67	−0.7	13	5,190	sw.	32	sw.	16
Kalispell	49	40	52	1.46	−0.6	11	4,156	nw.	39	sw.	16
Miles City	58	46	47	1.35	−1.3	6	4,257	ne.	34	nw.	30
Rapid City	59	49	48	1.97	−1.4	9	4,990	w.	30	nw.	6
Cheyenne	52	44	53	1.60	−0.1	10	6,287	w.	39	s.	21
Lander	52	41	48	0.44	−0.7	3	3,554	sw.	37	sw.	26
Sheridan	56	47	55	0.91	−1.1	10	2,389	nw.	22	nw.	24
Yellowstone Park	----	----	54	1.27	−0.6	8	5,285	sw.	33	sw.	23
Northe Platte	64	59	63	2.65	−0.6	9	4,803	s.	29	nw.	1
Middle Slape			**53**	**1.68**	**−1.6**						
Denver	55	44	46	0.62	−0.8	10	4,457	s.	25	n.	27
Pueblo	55	43	42	0.60	−0.8	4	4,350	nw.	26	sw.	30
Concordia	67	60	57	0.58	−3.8	2	5,507	s.	32	s.	10
Dodge City	64	57	54	1.46	−1.8	3	9,188	s.	34	sw.	10
Wicbita	67	61	60	5.50	+1.1	7	8,677	s.	33	s.	10
Oklahoma City	68	62	59	1.34	−2.3	5	6,346	s.	25	u.	5
Sauthern Slope			**56**	**1.70**	**−0.8**						
Abilene	67	60	55	1.22	−1.8	3	7,054	s.	34	sw.	12
Amarillo	62	55	53	0.69	−2.2	4	6,320	se.	26	e.	14
Del Rio	71	67	69	3.98	+1.4	7	5,930	se.	32	nw.	9
Roswell	60	49	46	0.93	−0.7	7	5,251	se.	29	ne.	15
Southern Plateau			**36**	**0.57**	**+0.2**						
El Paso	59	43	31	1.34	+0.8	6	5,530	e.	44	sw.	3
Albuquerque	55	40	36	0.53	----	4	3,456	sw.	20	c.	15
Santa Fe	50	35	37	0.85	−0.2	4	3,747	sw.	21	s.	21
Flagstaff	46	----	50	0.96	----	7	5,524	sw.	25	s.	8
Phoenix	61	42	25	0.02	0.0	1	3,780	e.	22	e.	29
Yuma	65	51	38	T.	−0.0	0	3,369	w.	17	s.	4
Independence	52	----	----	0.62	+0.5	2	----	s.	----	----	----
Middle Plateau			**34**	**0.37**	**−0.1**						
Reno	48	36	44	0.40	+0.1	5	4,990	w.	27	w.	14
Tonopah	48	34	33	0.25	----	3	----	se.	----	----	----
Winnemucca	49	33	36	0.69	0.0	2	4,770	sw.	27	nw.	27
Modena	47	30	33	0.18	−0.1	3	8,742	sw.	47	sw.	16
Salt Lake City	54	38	31	0.33	−0.5	3	5,588	s.	37	ne.	8
Grand Junction	54	35	30	0.26	−0.1	5	4,700	se.	28	s.	28
Northern Plateau			**46**	**0.89**	**−0.2**						
Baker	49	39	54	0.72	−0.6	7	3,287	n.	17	s.	25
Boise	52	39	42	0.12	−0.8	4	3,306	nw.	22	nw.	15
Lewiston	----	----	----	1.48	0.0	9	2,408	e.	21	uw.	1
Pocatello	51	38	39	0.09	−1.0	2	4,843	se.	41	sw.	16
Spokane	51	41	50	0.87	−0.4	9	4,144	s.	22	sw.	17
Walla Walla	54	43	47	2.01	+0.9	12	2,832	w.	14	w.	2
Yakima	53	41	47	0.91	+0.3	6	3,844	nw.	22	nw.	2
North Pacific Caast Region			**74**	**4.40**	**+0.3**						
Nortb Head	53	52	90	6.02	+3.7	19	8,966	n.	55	s.	25
Port Angeles	----	----	----	3.35	+2.5	16	3,317	sw.	21	w.	1
Seattle	53	48	70	3.35	+2.0	16	5,179	s.	28	w.	26
Tacoma	----	----	----	3.84	+2.4	15	4,910	n.	23	w.	26
Tatoosh Island	52	50	88	6.99	+3.8	17	6,853	sw.	35	e.	13
Medford	53	44	60	3.49	+2.8	9	4,158	nw.	24	nw.	22
Portland, Oreg	56	50	68	3.13	+1.6	16	3,296	nw.	20	w.	28
Roseburg	54	48	66	5.02	+3.9	9	2,616	u.	22	sw.	25
Middle Pacific Coast Region			**66**	**0.60**	**+0.3**						
Eureka	54	51	83	1.33	+0.6	6	4,558	n.	27	nw.	29
Red Bluff	59	46	43	0.99	+0.5	3	4,327	s.	24	se.	5
Sacramento	59	53	62	0.29	+0.1	3	5,961	s.	26	sw.	5
San Francisco	55	52	74	0.32	+0.1	3	5,753	sw.	28	nw.	27
San Jose	----	----	----	0.07	−0.0	3	4,426	nw.	24	sw.	5
South Pacific Coast Region			**63**	**0.38**	**+0.3**						
Fresno	58	46	46	1.12	+1.0	3	5,991	nw.	23	nw.	13
Los Angeles	61	56	66	0.02	−0.1	1	2,963	sw.	17	nw.	25
San Diego	63	60	78	0.01	0.0	1	3,911	sw.	16	w.	21
West Indies											
San Juan, P. R.	----	----	----	9.45	+4.2	16	6,444	e.	27	u.	12
Panama Canal											
Balboa Heights	----	----	[1]89	7.81	−0.2	22	3,465	nw.	25	nw.	12
Cristobal	77	76	[1]83	9.26	−4.4	22	4,187	se.	22	nw.	1
Alaska											
Fairbanks	48	41	63	1.73	----	9	2,991	sw.	20	nw.	11
Juneau	49	44	74	5.10	----	14	3,086	s.	15	se.	22
Hawaiian Islands											
Honolulu	70	67	72	0.18	−0.7	8	6,294	e.	24	e.	22

District and station	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
				0–10	In.	In.
Northern Slope				**5.1**		
Billings	11	12	7	----	0.0	0.0
Havre	6	16	8	5.7	0.0	0.0
Helena	5	9	16	6.8	9.0	0.0
Kalispell	3	17	10	6.4	0.0	0.0
Miles City	11	16	3	4.3	0.0	0.0
Rapid City	13	13	4	4.2	0.0	0.0
Cheyenne	10	14	6	5.1	0.0	0.0
Lander	15	11	4	4.0	0.0	0.0
Sheridan	7	17	6	5.1	0.0	0.0
Yellowstone Park	4	17	9	----	0.0	0.0
Northe Platte	14	10	6	4.3	0.0	0.0
Middle Slape				**3.7**		
Denver	10	15	5	5.0	0.0	0.0
Pueblo	11	18	1	4.0	0.0	0.0
Concordia	19	6	5	3.5	0.0	0.0
Dodge City	22	7	1	2.1	0.0	0.0
Wicbita	17	8	5	3.5	0.0	0.0
Oklahoma City	14	12	4	4.2	0.0	0.0
Sauthern Slope				**4.0**		
Abilene	9	12	9	5.1	0.0	0.0
Amarillo	21	8	1	2.8	0.0	0.0
Del Rio	9	16	5	5.2	0.0	0.0
Roswell	18	11	1	2.9	0.0	0.0
Southern Plateau				**3.0**		
El Paso	21	9	0	2.1	0.0	0.0
Albuquerque	12	12	6	4.2	0.0	0.0
Santa Fe	11	14	5	4.0	0.0	0.0
Flagstaff	10	12	8	----	0.0	0.0
Phoenix	20	6	4	2.9	0.0	0.0
Yuma	23	7	0	1.6	0.0	0.0
Independence	19	7	4	----	0.0	0.0
Middle Plateau				**3.8**		
Reno	17	8	5	3.4	0.0	0.0
Tonopah	----	----	----	----	----	----
Winnemucca	16	10	4	3.5	0.0	0.0
Modena	14	12	4	3.7	0.0	0.0
Salt Lake City	11	12	7	4.2	0.0	0.0
Grand Junction	13	12	5	4.3	0.0	0.0
Northern Plateau				**5.5**		
Baker	7	11	12	6.0	0.0	0.0
Boise	10	12	8	5.0	0.0	0.0
Lewiston	6	12	12	6.3	0.0	0.0
Pocatello	8	19	3	4.8	0.0	0.0
Spokane	5	13	12	5.9	0.0	0.0
Walla Walla	11	8	11	5.3	0.0	0.0
Yakima	13	6	11	5.3	0.0	0.0
North Pacific Caast Region				**6.4**		
Nortb Head	3	10	17	7.3	0.0	0.0
Port Angeles	8	7	15	----	0.0	0.0
Seattle	4	14	12	6.6	0.0	0.0
Tacoma	4	16	10	6.5	0.0	0.0
Tatoosh Island	6	6	18	7.0	0.0	0.0
Medford	12	7	11	5.4	0.0	0.0
Portland, Oreg	7	6	17	6.8	0.0	0.0
Roseburg	13	8	9	4.9	0.0	0.0
Middle Pacific Coast Region				**3.7**		
Eureka	12	8	10	5.2	0.0	0.0
Red Bluff	15	11	4	3.9	0.0	0.0
Sacramento	25	3	2	1.6	0.0	0.0
San Francisco	10	12	8	4.5	0.0	0.0
San Jose	18	9	3	3.1	0.0	0.0
South Pacific Coast Region				**3.5**		
Fresno	19	8	3	2.8	0.0	0.0
Los Angeles	13	14	3	3.6	0.0	0.0
San Diego	15	9	6	4.2	0.0	0.0
West Indies						
San Juan, P. R.	4	15	11	6.4	0.0	0.0
Panama Canal						
Balboa Heights	0	1	29	8.5	0.0	0.0
Cristobal	0	5	25	9.0	0.0	0.0
Alaska						
Fairbanks	3	19	8	6.0	1.2	0.0
Juneau	6	9	15	6.8	0.0	0.0
Hawaiian Islands						
Honolulu	16	13	1	3.8	0.0	0.0

[1] Observations taken bihourly. [2] Pressure not reduced to mean of 24 hours.

NOTE.—The data for Table 2, not baving been received in time from the Canadian Meteorological Service, will be published in tho July REVIEW.—*Ed.*

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LIGHTNING INVESTIGATION AS APPLIED TO THE AIRPLANE [1]

By A. O. Austin, Chief Engineer, The Ohio Insulator Co.

While the lightning hazard to airplanes or any aircraft is very small compared to many everyday risks, this hazard receives much attention. Although lightning has caused a few fatalities, it would seem that many cases of trouble due to other causes have been unjustly charged to lightning. Once the effect of lightning upon the pilot or plane is recognized, steps can be taken to materially reduce if not eliminate the hazard, although this may be small at most.

The studies made in the high voltage laboratory of the Ohio Insulator Co. for Ward T. Van Orman in testing out his protection for free balloonists, and the series of tests run on planes and other equipment furnished by Popular Mechanics, provide some rather interesting information. An attempt will be made to cover some of these studies briefly.

Since the tests run in connection with free balloons illustrate certain phases of the subject to better advantage than those upon airplanes, this matter will be treated first.

In running the series of tests balloon baskets, small size balloons, model airplanes as well as full sizes air planes were placed between a large electrostatic condenser and ground on the test field. The condenser may be regarded as a charged cloud and a discharge taking place between this cloud and ground can be made to strike the equipment under test. Figure 1 shows a discharge taking place from this condenser to ground, the photograph being taken by a synchronized camera.[2]

In general the hazards from lightning may be divided into two classes:

(A) Electrical or physical shock, which may affect the pilot and passengers.

(B) Those hazards which damage the plane or aircraft.

It would seem that the hazard due to the direct electrical or physiological effect of lightning upon the pilot or passengers should receive first consideration, rather than the damage to the aircraft. Unfortunately it is very difficult to obtain information upon this point owing to the variation in the personal element itself, and the hazard of making studies which may be exceedingly dangerous. It may be said, however, that as the size of aircraft increases the direct danger to pilot or passengers tends to decrease providing ordinary precautions are taken in the design and construction of the aircraft. This is due to the greater distance of the crater or point of contact of the lightning from pilot and passengers.

Hazards to the plane or aircraft.—These hazards may be classified as follows:

1. Fire hazard due to ignition of combustible material used in the construction of the plane.
2. Fire hazard due to ignition of explosive gases.
3. Weakening or destruction of metal or other parts due to current in the discharge.
4. Breakdown of insulation in the ignition system.
5. Back fire or preignition.
6. Damage to instruments.
7. Damage to rotating parts due to passage of current.
8. Sudden change in pressure on adjacent surfaces.

Electrical or physiological shock to pilot or passengers.—The experience of free balloonists throws considerable light upon the hazard due to shock, and means of protection. The fatalities in Belgium and Pittsburgh of recent years caused Van Orman to give this matter considerable attention.

In the Pittsburgh race Van Orman's balloon was struck by lightning while at an altitude of 3,000 feet and set on fire, and Morton, who was with him in the basket, was killed by the stroke. The 26 R. C. A. portable loop radio set which was between Van Orman and Morton appeared to be badly damaged. However, an investigation showed that the set was not damaged electrically. Van Orman was apparently conscious for a short time after the stroke. He then lost consciousness and apparently remained in a stunned or dazed condition for five or six hours after the parachuting balloon struck ground.

Wollam and Cooper in the *City of Cleveland* had a somewhat similar experience, the stroke of lightning apparently passing over the surface of Cooper's leather jacket or suit which was wet at the time. The shunt path provided by the suit apparently saved Cooper's life, although he was badly burned by the stroke. Wollam escaped uninjured and attempted to lift Cooper and his parachute out of the basket, but was unable to do so. Cooper apparently is the only known person to suffer a heavy direct stroke and still live to tell about it.

These incidents show that a stroke of lightning may be very close to a person without causing any serious injury. Had the pilots been subject to the same condition while flying an airplane, it is possible that they might have lost control of the plane causing it to crash.

Figure 2 shows the basket used on the *City of Cleveland* balloon which was struck while the balloon was at least 5,000 feet in the air.

The photograph shows the basket with a dummy in place being subjected to an artificial lightning discharge. The steel cables from the ring to the basket were not bonded to the reinforcing wires which were used in making up the basket. It is possible that had bonding been carried out, the results might have been quite different.

In the tests shown in Figure 2, the collapse of the electrostatic field caused an induced potential of over 25,000 volts between the dummy and the lower part of the basket. While the energy is not large, the discharge might tend to frighten or startle one similar to a shock one receives in coming in contact with a metal object

[1] Communicated by W. T. Van Orman, Goodyear Zeppelin Corporation, Akron, Ohio.
[2] All figures are grouped on inset sheets at end of article.—*Editor.*

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after picking up a charge in walking over a carpet in cold dry weather.

Figure 3 (not reproduced) shows the metal reinforcing wire fused due to the discharge of lightning. It will be noticed that the horizontal wire crossing the vertical wire has been burned in two, as well as some of the basket material. An examination of the basket showed a large number of burns where the reinforcing wires crossed each other.

Figure 4 shows a test on Van Orman's lightning protecting scheme. The protection consists essentially of a cage formed by conductor hanging freely. These conductors are bonded at the top and part way down, but left entirely free at the bottom so as not to interfere with landing or parachute jumps from the basket. The conductors forming the shunt path are moved outward from the basket a short distance. The cable supporting the basket to the ring has been replaced with rope. It would seem that had this device been used in the flights in Belgium and Pittsburgh, the fatalities due to direct stroke would have been eliminated.

Apparently there is little difficulty in shunting the main discharge, but there is some question as to how far the discharge should be from the pilot so that he will not be stunned or frightened to the extent of losing control. The baskets in racing balloons are rather small, and anyone in the basket must of necessity be very close to any discharge striking the basket. Should the Van Orman cage give the necessary protection for direct hits, it would go to show that the protection to pilot or passengers in an airplane may be easily provided by shunting the discharge a short distance to one side.

Danger of direct hit.—Many people believe that a balloon or airplane should not be subjected to a lightning stroke while flying, since there is no direct ground connection. Any object which has a greater conductivity than the air or a greater electrostatic flux carrying capacity will tend to disturb the electrostatic field and will cause a discharge in the immediate vicinity to take a path along the object.

Effect of construction upon a stroke of lightning.—In running the tests on the Van Orman cage, an attempt was made to protect the balloon. If the gas in the balloon is free from air, lightning will not cause it to explode although the balloon may be set on fire. If an explosive mixture is present in the balloon, an explosion may take place due to the ignition of the mixture.

Difference between a wet and a dry balloon.—In the study of high voltage phenomena, particularly those applicable to transmission line structures using wood, it was believed that there would be a considerable difference between a wet and a dry balloon. The tests were very interesting in this connection, as they go to show that while there might be a considerable difference in aircraft which is constructed of metal and that primarily of nonconducting material, when dry there would be little difference where the latter was wet. This difference is undoubtedly due to the increase in electrostatic capacity due to the presence of water.

Figure 5 shows a hydrogen filled balloon being subjected to an artificial stroke of lightning. The balloon has a conductor attached approximating a long antenna, hanging from the lower side. A number of discharges were applied to the balloon similar to that in Figure 5. All of these discharges struck to the upper part of the conductor attached to the balloon, and then from the lower end of this conductor to ground.

As soon as the balloon was wet, however, conditions were entirely changed, the performance being similar to that shown in Figure 6. The discharges instead of going directly to the antenna and then to ground, struck the surface of the wet balloon. The discharge in Figure 6 is apparently passing along the surface, which destroyed the balloon in all cases. The discharge invariably burned the rubber and set the escaping gas on fire. Had the photograph been taken a fraction of a second later, the balloon would have been collapsed, the duration of the arc shown in the photograph being less than one half microsecond.

These tests go to show that there is little or nothing to be gained electrically by the use of nonconducting material in the aircraft structure where the material becomes wet, as the electrical fields set up are not materially different.

A discharge striking conducting material adjacent to inflammable material is likely to set the latter on fire. There are many cases which illustrate this point. Owing to the tendency of a discharge to strike a wet balloon, it was evident that it was necessary to remove the point of contact of any conducting system some distance from the balloon. While this is a distinct disadvantage to racing balloons, owing to increased weight, the tests are very interesting as they show the tendency of the wet fabric in diverting a discharge.

Figure 7 shows a discharge to ground some few feet distant from a balloon equipped with a cage or lightning rods. In Figure 8 the balloon has been wet. While there was some tendency for the balloon while dry to attract the arc, the point of discharge was too great, so that the arc struck to ground. In Figure 8, however, the field set up by the wet balloon was of sufficient magnitude to attract the discharge. The discharge followed the shunt path, then continued from the lower end of the cage to ground. Without the shunt path, the wet balloons were invariably set on fire by the direct stroke. In some cases the fabric seemed to be only slightly damaged. The escaping gas, however, was frequently ignited by the stroke, causing destruction of the balloon unless quickly extinguished.

The probability of a direct hit.—In the case of free balloons or blimps there would undoubtedly be a considerable difference between the wet and dry conditions in attracting a discharge in the vicinity. In other aircraft as now constructed, however, there would be little difference, wet or dry. In the tests on models placed near the path of discharge it was evident that the path of discharge was diverted an appreciable distance by the presence of the plane. It would seem that the probability of being struck would increase approximately as the square of the greatest linear dimension.

The nature of the electrical field, the polarity of the discharge, and the direction of the axis of the aircraft relative to the general path of discharge, are all factors which make it difficult to predict the effect of size in increasing the probability of direct hits. Figures 9, 10, 11, and 12 (fig. 10 only reproduced) show typical discharges to model planes showing the probable points of contact of the stroke.

Figure 13 shows a positive discharge of limited capacity striking a model Zeppelin. The discharge was not sufficient to cause the arc to continue to ground, but illustrates the effect of a large body free of ground. Immediately following the first discharge, another discharge was applied of sufficient magnitude to cause a discharge

not only to the model Zeppelin but from the rudder to the ground.

It is interesting to note that in all of the tests the fabric used on the Zeppelin and that on the fabric-covered duralumin airplane was not ignited by the discharges. This goes to show that the fire hazard is negligible where a path of high electrical conductivity is provided.

It would seem that the effective increase in size and the use of metal in the present construction of airplanes should do much to minimize the lightning hazard, even though little or no attention is given to protection.

A direct hit to the plane may possibly affect the pilot or passengers in one of the following ways:

(*a*) Direct hit.

(*b*) By forming a path for the discharge between conducting objects.

(*c*) Shock from induced charge.

(*d*) Sudden change in air pressure.

(*e*) Severe sound or pressure waves.

(*f*) Currents induced in the body by an electromagnetic field.

(*g*) Hazard due to the effect of intense light upon the pilot.

While the danger from some of these hazards may be absent in many planes, they can be largely reduced if not entirely eliminated in others by proper attention to details of construction, or by applying a protecting scheme which will establish the path of discharge at a distance from the pilot.

(*a*) *Direct hit.*—In general the possibility of a direct hit to the pilot is exceedingly small even in the low wing monoplane with open cockpit. The tests showed that the discharges would enter or leave through the propeller or nose, rudder, wing tips, or landing gear. A lightning rod projecting above and to one side of the pilot would insure the diverting of the stroke even though the pilot's head projected well above the fusilage. In large planes or Zeppelins the points of contact of the stroke would be considerably removed from the pilot or passengers, so that it would appear that the danger from direct stroke may be even less than that in the ordinary dwelling during an electrical storm.

(*b*) *By forming a path for the discharge between conducting objects.*—A discharge of lightning may carry a current far in excess of that available in any of the laboratories used for the production of artificial lightning. The fused wire in the basket shown in Figure 2 (not reproduced) can not be duplicated with the heaviest lightning discharges in the laboratory. Records taken at the forest rangers' stations show that a stroke of lightning may be sufficient to fuse a No. 14 copper wire. Tests on aerials have shown that wire of larger size is fused, all of which indicate currents exceeding several hundred thousand amperes.

The impedence afforded by conductors with this very high rate of discharge will cause a considerable drop in potential. This drop in potential causes the current to divide into multiple paths, the drop in voltage being sufficient to cause the bridging of appreciable air gaps where the impedance is not very large. It is therefore essential that the most careful attention be given to bonding. In order to reduce the impedance it is well to distribute the conductor in several parallel paths. This reduces the reactance and the voltage induced by the high rate of discharge.

It is evident that should the pilot come in contact at two points along a conducting member, he is likely to be subject to shock. The thorough bonding, the use of a low impedance multiple path as far away from the pilot as possible, together with a single point of contact with conducting material will eliminate the danger of shock from drop in potential due to the passage of exceedingly large currents.

(*c*) *Shock from induced charge.*—A pilot in an open cockpit may be subjected to an induced charge due to the collapse of the electrostatic field. It would seem that this charge would amount to but little providing the discharge did not cause the pilot to become frightened so as to lose control. The complete shielding afforded by metal cabin planes completely eliminates the effect of the induced charge due to the collapse of the electrostatic field. The same applies to Zeppelins.

(*d*) *Sudden change in air pressure.*—The intensity of lightning varies greatly for different strokes. It would seem, however, that the very severe discharge causes a rapid heating of the air and an increase in pressure in the immediate vicinity. The pressure set up where the air is free to expand is not as great as originally supposed. The fact that three balloonists have come through storms where the stroke was within a foot or two of them would indicate that the hazard from this source is not serious, even for the very heaviest discharges where the path can be moved out a few feet from the pilot.

(*e*) *Severe sound or pressure waves.*—The effect of the severe sound and pressure waves may be responsible for the shock suffered by pilots and others who have been within a few feet of lightning strokes. The duration of the effect seems to vary considerably with the individual, and may cause effects somewhat similar to those suffered from shell shock. Many of the factors producing shell shock are present although there are others in addition. The severity reduces rapidly with distance. It would therefore seem that using a construction which removed the point of contact between lightning and plane well away from the pilot will do much to eliminate any serious effects which may cause the pilot to lose even temporary control.

The pilot can, of course, be easily protected from sound or pressure waves by providing a suitable compartment or other sound-absorbing equipment.

(*f*) *Currents induced in the body by an electromagnetic field.*—A stroke of lightning may consist of a single discharge or several discharges within a very short space of time. The strength of the electromagnetic field will vary directly as the current in the discharge, and inversely as the distance. A current of 400,000 amperes in a stroke will produce a field of 2,620 maxwells at 1 foot distance; 262 maxwells at 10 feet distance, and 131 maxwells at a distance of 20 feet.

Any change in the electromagnetic field passing through either high or low resistance material will induce a voltage and current. The induced voltage and current will depend upon the rate of change in the magnetic field. It is evident that the lines of force passing through a person will induce currents, the action being similar to that in a high-frequency furnace. Several strokes in rapid succession may induce a greater current or potential than a single stroke of higher maximum magnitude but having a slower rate of change.

While it is possible to screen the electrostatic field, it is practically impossible to effectively screen the electromagnetic field so as to prevent the lines of force passing through objects in the vicinity of the field. The field may be set up by the current of a portion of the discharge in the air, or in a conductor in the aircraft. It would seem that the heaviest discharges taking place close to a person

may induce enough potential and current to effect the system, or at least paralyze the nervous system temporarily.

A study of the factors affecting the induced potential and current goes to show that the electromagnetic field may be materially reduced by removing the shunt path from the immediate vicinity, and by forming multiple paths around the pilot or passengers so that the field set up by the current in one path tends to neutralize the field set up in the other. The fact that some people have not been affected although within a few feet of the discharge would indicate that a reduction of the field strength by an appreciable amount would entirely change conditions and provide protection even for the most severe strokes.

Further investigation may show that the induced current does not constitute a hazard. The magnitude of the voltage generated and the current induced for heavy strokes in the immediate vicinity, however, would indicate that the possibility of affecting at least the nervous system can not be ignored without very definite proof to the contrary.

Although little has been accomplished in determining whether or not the shock or stunning effect is primarily due to electrical causes or to physical conditions similar to those producing shell shock, the same method will improve conditions for either case—which consists primarily in initiating the point of contact to the stroke as far away from the pilot as possible.

(g) *Hazard due to the effect of intense light upon the pilot.*—The light from a stroke particularly at night may have the effect of blinding the pilot when passing through the line of vision. At night the iris is wide open, and it is possible that the ultra-violet light might have some effect upon the pilot for a discharge striking the nose of the plane. In most planes, however, the discharge would be to one side and above or below the direct line of vision. It is believed that the hazard from this cause is small. While intense light may have the effect of blinding the pilot for a short time, any serious effect due to ultraviolet light may be eliminated by the use of glass in the windows or goggles which would absorb any injurious rays.

While the effect of lightning upon the pilot or passengers undoubtedly causes the greatest and most uncertain hazards, there are other hazards to the plane or aircraft which need careful consideration.

1. *Fire hazard due to ignition of combustible material used in the construction of the plane.*—The fire hazard to the metal plane is negligible although intense heat exists at the point of contact with the lightning and the plane. The fire hazard is practically negligible even where material which will support combustion is used. Where an inflammable covering is used in contact with metal, the fire hazard is apparently negligible. Inflammable material which is readily ignited may be set on fire by the crater. The severe rush of air following the stroke has the effect of extinguishing the flame, the discharge being in the nature of an explosion. The rapid expansion of the gases even in the fabric apparently absorbs sufficient heat, which together with the blast of air following the discharge prevents ignition. This is particularly true where a fabric is used to cover duralumin or other metal. The heat conduction of the metal and the low resistance of the path afforded tend to not only absorb the heat but reduce the energy dissipated.

Figure 14 (not reproduced) shows the effect of artificial lightning upon the rudder. It will be noted that the fabric has apparently been exploded at the points of contact, the fibers being torn apart, the effect being very similar to that of popping corn.

A rather severe series of tests run on a model Zeppelin covered with fabric showed that it was impossible to ignite this fabric with the artificial lightning. The history of Zeppelins has also indicated that this danger is small unless conditions approximate those of the gas-filled free balloons.

2. *Fire hazard due to ignition of explosive gases.*—A discharge may take place between conducting surfaces not properly bonded, or from isolated tanks or conductors separated from the bonded structure by small air gaps. The discharge may be produced by the release of a bound charge following the collapse of the electrostatic field, or due to the impedance drop in conductors making up the structure, or by the change in the electromagnetic field. These induced discharges are similar to those noticeable in the ordinary dwelling where a discharge takes place between wiring and conduit or fixtures following a stroke of lightning near by. Should these discharges take place in a pocket of gas, an explosion may result. It is therefore important to either thoroughly ventilate all pockets which may accumulate gas or to adopt a construction so that a discharge can not take place. Vents or openings for scavaging explosive gases should be protected with a screen similar to that used in a safety lamp.

3. *Weakening or destruction of metal parts due to current in the discharge.*—In aircraft having a metal structure there is ample conducting capacity so that a serious temperature will not be reached in any of the metal parts. However, should the construction be such that the current is confined to small members or to important connections having a high resistance, it is possible that the heating may seriously affect the structure and lower the mechanical strength. This is important, as some of the alloys are materially affected by a temperature far below the fusing point.

While the varnishing of the surfaces and joints together with the oxidation of the surface go to produce a joint of high resistance, it must be remembered that the riveting cuts through the edge and forms a path of low resistance. A number of point contacts formed in this way results in a joint of very low resistance so that little or no damage need be feared even though cross section of metal in good contact is small. Where metal parts simply come in contact or are held a short distance apart, considerable energy may be dissipated in the joint.

It would seem that the greatest hazard due to heavy current affecting the strength of metal parts is that due to control cables or stay wires in nonmetal planes. Discharges direct to the rudder showed a very appreciable rise of voltage on the control cable, although in the plane tested a small percentage of the current only was carried by the control cable—the major part going through the hinge and metal framework.

4. *Breakdown of insulation in the ignition system.*—Most of the ignition systems are fairly well insulated and have to withstand the relatively high voltages generated in the normal operation of the engine. Care should be taken so that conductors of the ignition system do not form a shunt path. In addition, the conductors should be exposed as little as possible. The ignition systems apparently are more immune from trouble than would generally be expected. This seems to be due to the fact that the rise in voltage is limited by the discharging of the spark plug either inside or outside the cylinder.

Figure 15 (not reproduced) shows the ignition system being subjected to a discharge of over 1,500,000 volts. The discharge is striking the spark plug and lead on one of the cylinders. A number of similar discharges apparently had no effect upon the magneto or other parts of the ignition system. A small shield placed over the plug easily diverted the discharge.

5. *Back fire.*—It is evident that a discharge striking a plug or lead may cause a back fire or the engine cylinder to fire out of turn. A series of tests were made with the engine running so that the discharge would strike the propeller or ignition system. The propeller used was wood with a metal shielding which ended some distance from the hub.

Figure 16 shows a discharge striking the end of the propeller. The discharge is then shown jumping from the metal shielding on the propeller to one of the spark-plug terminals, as these happen to end about in line with the end of the shielding. A number of discharges apparently had no effect although it appeared that the impulse from one cylinder was lost. The effect, however, was so slight as to leave this point in doubt. A small shield placed in front of the rod effectively drew all of the discharges. While the hazard is exceedingly small, it would therefore seem to be good insurance to prevent a discharge of this kind to the ignition system which might break down the insulation of leads or the magneto.

6. *Damage to instruments.*—During one of the endurance flights at Cleveland the plane was struck by lightning and the instruments so damaged that landing was made. An examination of the instruments did not show any electrical damage due to the conduction of current. There was an indication that the diaphragm in the instrument which was connected to the Pitot tube used for determining velocity might have been damaged by the pressure set up. In the tests which were run some time later it was evident that the Pitot tube might be a point of contact for the stroke, in which case sufficient pressure might be set up so as to destroy the rather delicate diaphragm. A sudden air pressure set up by the stroke in any other way might of course have produced the same effect.

Should it appear that there is danger to instruments from the pressure set up, it would be a comparatively easy matter to prevent this by placing a baffle in the line between the Pitot tube and the instrument, preferably with a surge chamber between the restriction and the instrument. Other instruments could be inclosed in a chamber with a window.

The electrical fields set up by a heavy discharge in the immediate vicinity may damage magnetic instruments or those in which an induced current may cause a breakdown of insulation. While electrostatic screening is comparatively easy, screening for the electromagnetic field is very difficult and it would follow that instruments which are likely to be damaged by a strong magnetic field should be so placed that the path of discharge in the frame or surrounding objects is removed as far as possible.

7. *Damage to rotating parts from passage of current.*—The damage to rotating parts may be serious where a heavy current must pass through an important bearing. Discharges with currents as high as 100,000 amperes showed no appreciable damage on the main bearing, or upon ball bearings. Since this discharge lasted for a fraction of a microsecond only, the tests do not prove that damage from this source can be entirely ignored. In general, however, it would seem that a discharge striking a metal propeller would flash from the shaft to the face of the engine case without causing any damage. However, should the discharge take place in the bearing, it is possible that trouble would result. Owing to the resistance of the bearing, it is comparatively easy to provide a shunt path between the propeller shaft and housing so that the oil film will not be punctured by a discharge.

While the energy stored in the test condenser is of the order of 10,000 watt-seconds compared to 10,000,000 watt-seconds in the discharge of lightning, it must be remembered that the energy is dissipated almost entirely in heating the air so that the energy dissipated in a bearing may not be any more with a lightning stroke than that under laboratory conditions, unless the discharge consists of a number in rapid succession liberating a considerable amount of energy.

8. *Sudden change in pressure on adjacent surfaces.*—The sudden change in air pressure following a heavy stroke will probably not exceed that frequently occurring under normal flight. Should a discharge be close to and parallel a surface, it is possible that a heavy effective pressure may be set up tending to cause the collapse of same. It is this sudden change in pressure which probably accounts for the tearing of fabric.

It is evident that the larger the spread of the conducting surfaces the greater will be the danger of a stroke including the airplane in its path to ground, or from cloud to cloud. While the use of an aerial extending some distance below the plane will tend to increase the danger of a stroke it must be remembered that this will at least keep one of the points of contact of the discharge at some distance from the plane. This advantage may more than offset the increased probability of a strike. The use of a loop set does not change the hazard in any way over that where no radio set is used. The use of a strut or mast extending above the plane for an aerial would seem to be an added protection as it would tend to keep the point of contact at a distance.

The insertion of a resistane or impedance between the antennæ and instrument with a shunt path to the frame of the aircraft will provide ample protection, the protection probably being much more effective than that provided for the ordinary house radio set using an outside aerial.

While hot gas is a good conductor, the question of the engine exhaust forming a conducting path which would tend to induce a stroke to the plane does not seem to be an appreciable hazard. In all of the tests the effect of the exhaust gases could not be noticed. In the many tests made there was no indication that a low resistance or conducting path was created by the hot gases. In fact, it would appear that the dielectric strength of the air was apparently increased by the wind or pressure produced by the propeller. While the gases are conducting for a very short distance from the exhaust, this hot gas is soon cooled by the mixing of the strong air current produced by the propeller, so that no effect upon a discharge can be expected.

In conclusion it may be said that while information is lacking as to the effect upon the person, much can be accomplished to remove the danger of this effect by giving attention to the various factors involved. While the hazard is exceedingly small, it is possible that still further improvements may be effected by taking advantage as opportunities in design and construction present themselves.

Further information upon the effect of shock will doubtless show that the hazard is not very great, although

it may appear to be necessary to protect the pilot from sound or other conditions during a storm. Where the pilot has a fear of lightning, it is possible that tests or checks might be devised which would remove this fear.

Anything which will permit the safe landing of the plane or provide automatic control while the pilot is stunned would do much to eliminate the hazard that now exists. Owing to the increased reliability of aircraft, less attention will be paid to storms. While this will tend to increase the lightning hazard, it would seem that the present hazards can be more than offset by careful attention to the various factors tending to produce reliability.

OBSERVATIONS FROM AIRPLANES OF CLOUD AND FOG CONDITIONS ALONG THE SOUTHERN CALIFORNIA COAST

By JOSEPH B. ANDERSON, Lieutentant, United States Navy

[United States Naval Air Station, Anacostia, D. C., July, 1931]

While serving as aerological officer of the aircraft squadron, Battle Fleet, at the fleet air base, San Diego, Calif., during the summers and autumns of 1928 and 1929, many previously formed ideas of the California weather underwent a considerable change. Perhaps the most interesting of these was that, in so far as aerological officers and aviators are concerned, the weather lacks much of the regularity which had been expected from the claims of the Californians and descriptions of tourists. It is true that over the land adjacent to the ocean there is little rain during the summer, few thunderstorms and gales, and that the sky generally becomes cloudy during the night with clouds that burn off early the next morning, leaving the day more or less cloudless. (At sea the clouds may, or may not burn off, a fact of little concern to those on land but often vitally important to the aviator and navigator.) With this the regularity ceases, for the velo [1] clouds frequently form over land as early as 2 or 3 p. m., and continue until early morning, mid forenoon, or even until noon, at heights which vary from 1,000 to 4,000 feet, according to conditions. If the clouds form at an altitude of 2,000 feet or more, they are of little moment to the pilots of aircraft. However, when they develop at such an altitude that their bases are less than 1,000 feet, there is a considerable likelihood that they will continue to lower until they reach the surface, when, to all practical purposes, a dense fog results.

Since the flight operations are often delayed, cut short, and even rendered impossible by a velo cloud that fails to burn off at the usual time, or that forms earlier than the regular time, the aerological officer receives many inquiries from squadron commanders asking the time the sky will clear, the time that the clouds will form at night, what the ceiling will be, whether night flying is advisable, if the clouds will clear at sea during the day, and many similar questions. Obviously the answers to these questions are not always apparent.

During the summers of 1928 and 1929 many schemes were adopted in an effort to find the why and the wherefore of the southern California coast weather in the belief that if they were found, the when could be more easily determined. The current weather maps were available but did not explain many of the observed details. Old maps were studied in an attempt to classify them in accordance with certain very definite types of weather which were observed, but with little success. A study of the actual changes in the weather during these types proved to be more fruitful of results and accounted for many of the successful forecasts; but at times a very definite type would change suddenly, apparently without cause, and a more or less complete failure in the forecast would result. The lack of reports from the south and west made the identification of fronts difficult, and even impossible, much of the time. Further, meteorological literature was searched for a satisfactory explanation of presence of the velo cloud during the night and its absence during the day, at least over land. The explanations found did not appear to be of great practical value in forecasting the cloud conditions.

There remained, however, the aerograph records which had been made during the many aerological flights at the naval air station, and the opinion was soon formed that if an understanding of the velo cloud, and its many changes, were to be gained it would be from the visual observations and instrumental records obtained during flight. As stated, there were many records available, but these did not seem to give the detailed information desired. Practically all records made during the summer and autumn months showed that a temperature inversion existed over the air station during these seasons, and other records showed that the inversion was frequently present during the other seasons. This, of course, was already well known, as were the several theories which had been advanced to explain the cause of this condition, such as the Imperial Valley air theory and the settling air, or subsidence, theory. (The former states that the warm, dry air above the base of the temperature inversion [2] is air which has moved westward over the mountains from the Imperial Valley to the coast, while the latter explains the temperature and dryness of the upper air as due to the presence of the HIGH in the upper atmosphere over the semi-permanent thermal LOW at the surface in Lower California. The slow descent of air from this HIGH is given as the cause for the heat and dryness aloft.) The main points noted in the old records were that the temperature of the air decreased *rapidly* with the altitude until the base of the inversion was reached, then the temperature increased with continued increase in elevation to some definite point above which a more or less normal decrease in temperature occurred. The record showed that as a general condition the relative humidity increased from the surface to the base above which it decreased rapidly, usually to 50 per cent, or less; often to between 50 and 25 per cent; again, to less than 25 per cent; and occasionally to almost 0 per cent. However, it was found from observations during some of the aerological flights that there were inaccuracies in the temperature and relative humidity traces on the older records and also on the ones being made during the early summer of 1928. The inaccuracies in the relative humidity traces were caused by the type of humidity element installed on the aerograph, a type much too sluggish to record details during a routine climb. The temperature inaccuracies referred to were caused by the frequent delays in take off when the sun was shining. Experience showed that unless especial precaution were taken under these conditions a temperature of 2° to 5° C. above the true air temperature would be recorded at the time of the

[1] Velo cloud, the name given by Californians to the high fog or stratus cloud that drifts over land and generally burns off as the day advances.—*Editor.*

[2] For the sake of brevity the word "base" alone will be used on subsequent pages, the meaning in all cases being the same as in the present instance.

(To face p. 264)

FIGURE 1.—Discharge from large condenser to ground at the high voltage laboratory of the Ohio Insulator Co. Photograph taken by synchronized camera

FIGURE 2.—Showing the basket used on the *City of Cleveland* balloon which was struck while the balloon was at least 5,000 feet in the air

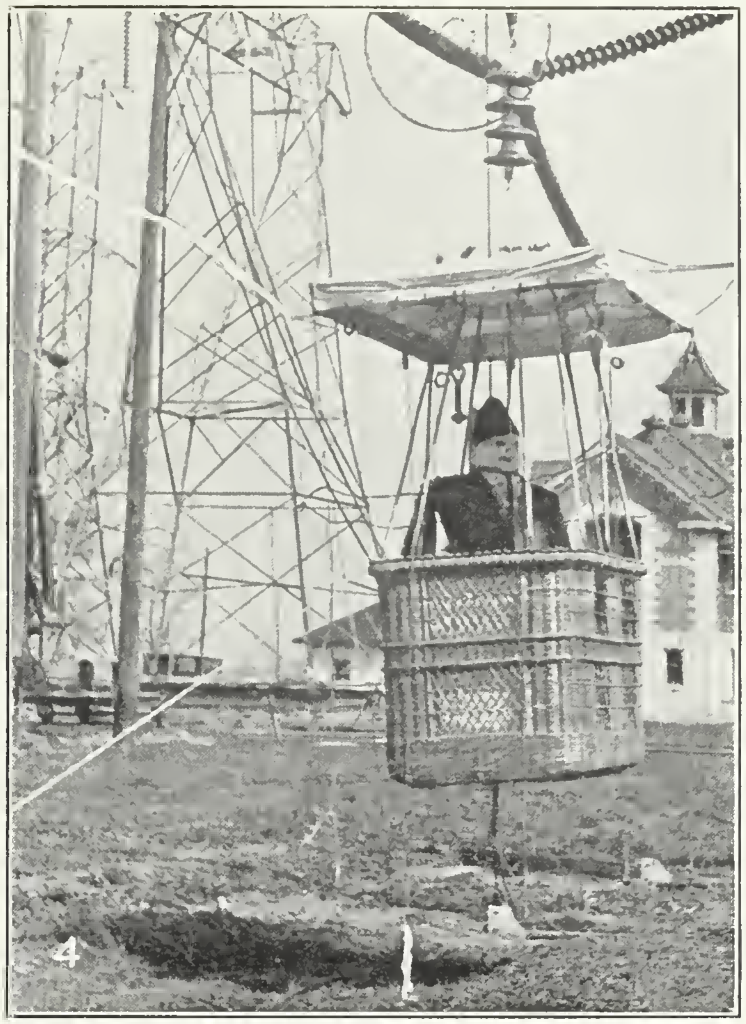

FIGURE 4.—Basket equipped with Van Orman cage for protection against lightning

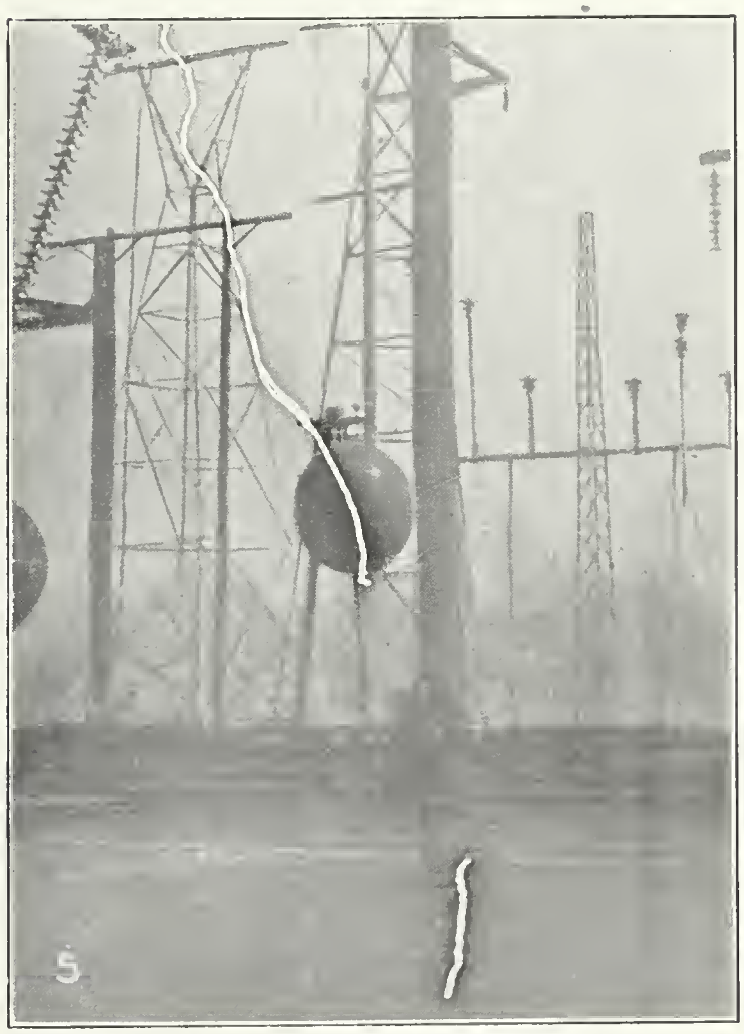

FIGURE 5.—Dry-hydrogen balloon with antennæ attached, subjected to lightning discharge without damage to balloon

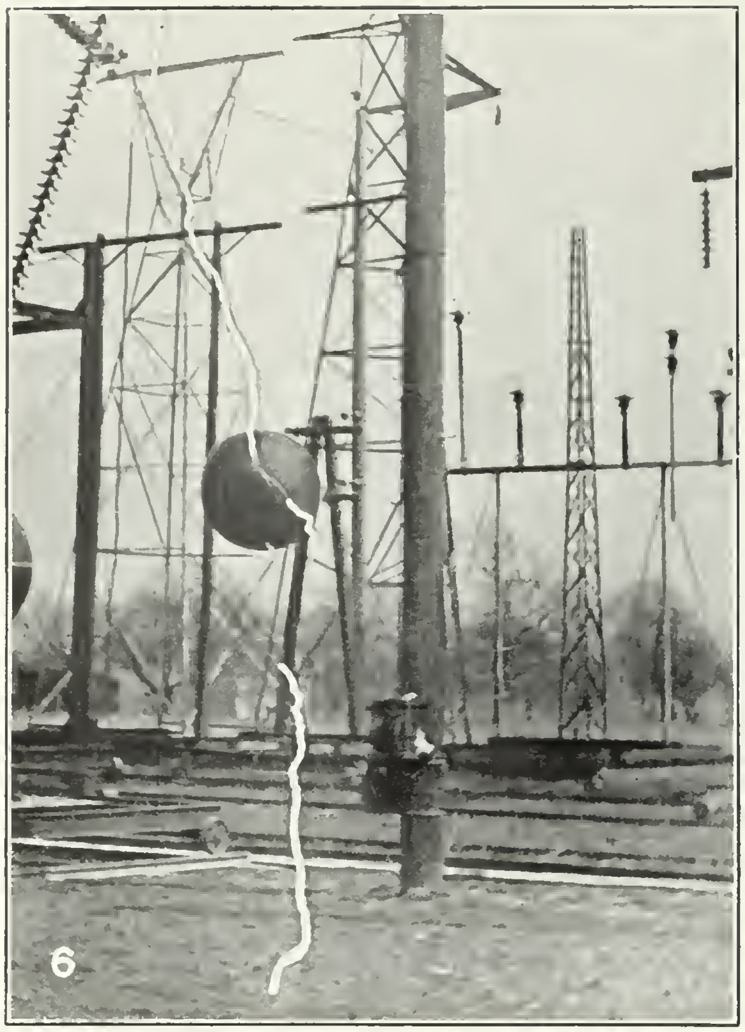

FIGURE 6.—Photograph shows discharge to the wet balloon causing its destruction

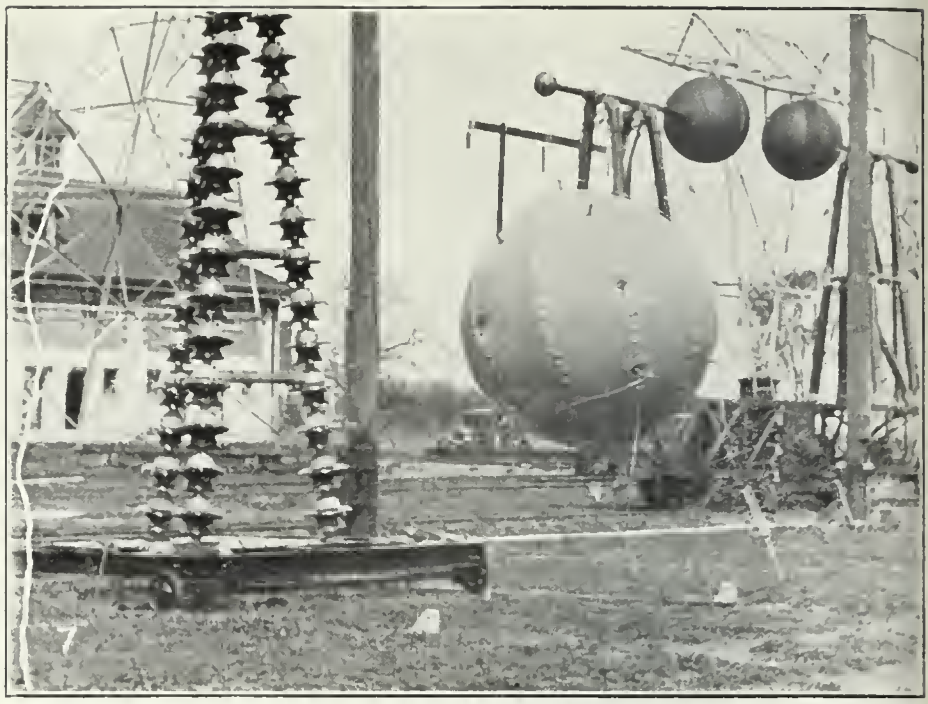

FIGURE 8.—The field set up by the wet balloon attracted the discharge which terminated on lightning rod raised from surface

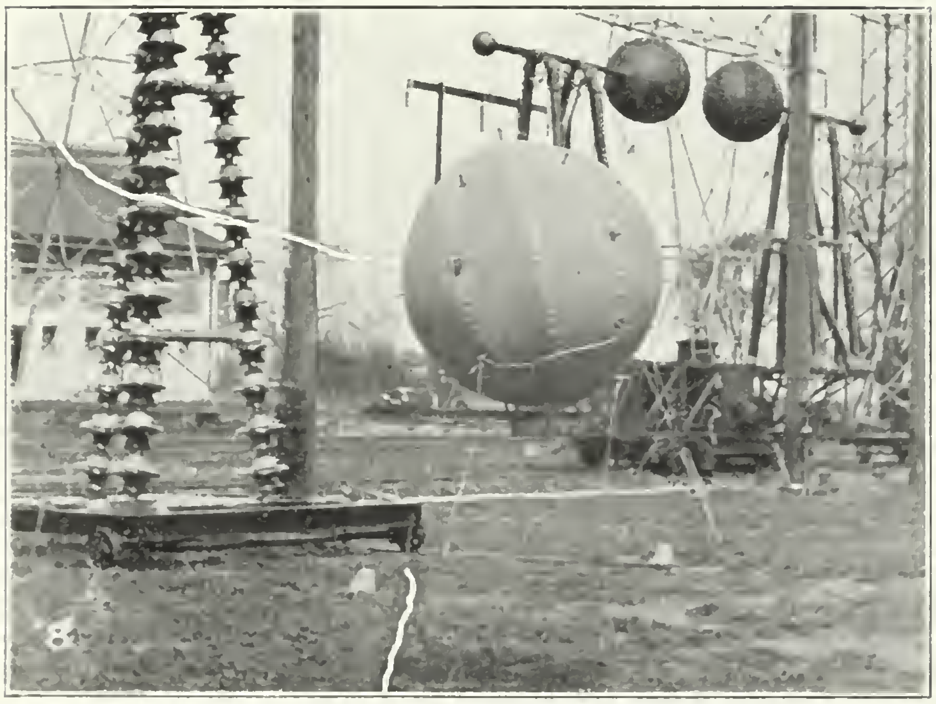

FIGURE 7.—Discharge taking place to one side of dry balloon equipped with cage and lightning rods

FIGURE 10.—Discharge entering and leaving from wing tip

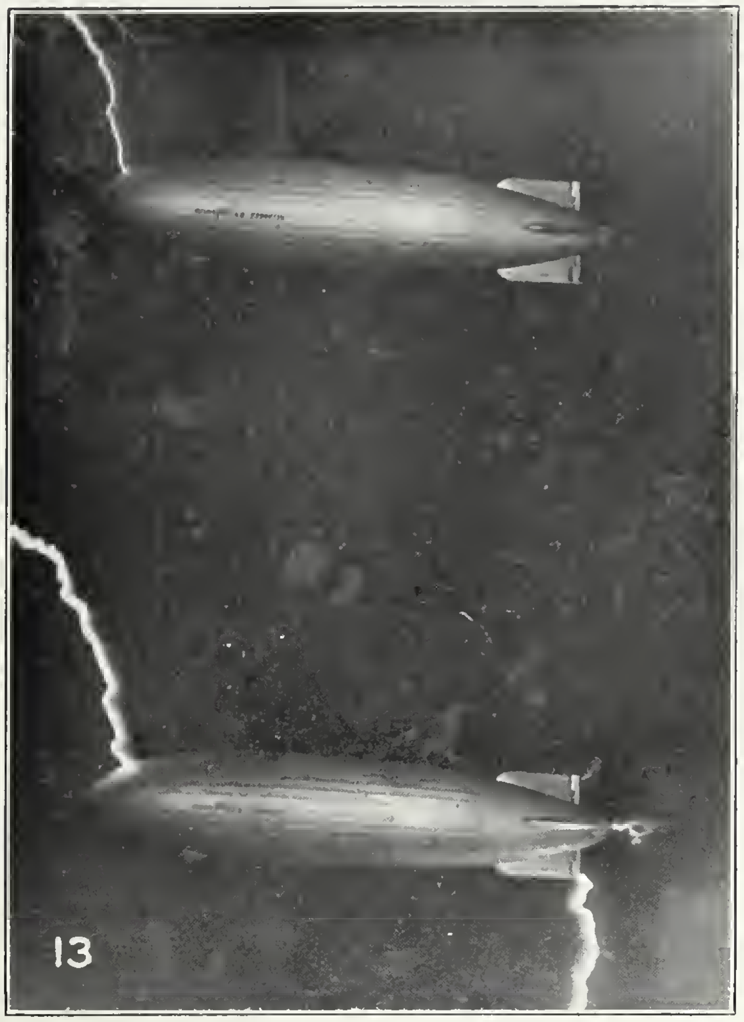

FIGURE 13.—Upper view: Discharge of limited capacity striking model Zeppelin. Lower view: Heavy discharge striking Zeppelin and continuing to ground

FIGURE 16.—Discharge to propeller while in operation. Discharge strikes from termination of metal on propeller to ignition system opposite

beginning of the flight and would, therefore, show a much too rapid fall in temperature from the surface to the base. The relative humidity records were greatly improved by the installation of new hairs in the aerograph, and the temperatures at take off were corrected for the naval air station by the introduction of certain modifications in the routine flights by Lieut. A. L. Danis, United States Navy, shortly after he reported for duty as aerological officer. Correct surface temperatures were more easily obtained by the aircraft squadrons' personnel since the flights were made from the water in a seaplane.

During 1928 routine aerological flights were being made daily, except Sundays and holidays, by the naval air station personnel, but because of the pressure of other duties only a limited number were made by the aircraft squadron's aerologist. During these flights, however, the opinion was soon formed that although the routine flights were of great value from the standpoint of information in general, they were not entirely suited to a study of this kind. This was due to the following causes: (1) being routine, they were scheduled for about the same hour each day; (2) the rate of climb, which was about 300 feet per minute, was too rapid for the recording of many details; (3) the length of the flight was usually quite limited owing to the fact that the data had to be worked up as soon as possible for use in the morning forecast and forwarding to the Weather Bureau, and also because of other operations scheduled for the plane.

During the summer and fall of 1929 it became possible to make many aerograph flights, not of a routine nature, to investigate special features of the local weather. Data gained from these flights, together with information received through conversation with officers who had cruised in various parts of the eastern Pacific Ocean, ship reports, and information obtained in the Weather Bureau office at San Francisco, led to a survey of the prevailing conditions along the coast and the adjacent ocean, and a study of their relation to the inversion and cloud conditions. This survey has shown that the inversion is normally a sea condition and exists over the land only in areas where surface air from the ocean has penetrated; that it is influenced at times by air from the Imperial Valley, or other inland districts, which is evident from the fact that pilot balloon records and observations of upper clouds and forest fire smoke show definite easterly winds aloft on many days; that much of the time inland air is not present, and therefore not necessary, because at times both surface and upper winds are from the sea for periods of several days. It is further quite evident that although the inversion does greatly influence the fog and velo cloud conditions, it is not the cause of either.

It was known that the inversion extended continuously along the coast from San Diego to San Francisco, and for a considerable distance to sea. It was also known to cover the land areas west of the Coastal Range and to exist over San Francisco Bay. During this survey it was learned that it extends north along the coast to the southern part of the State of Washington during the summer and, according to the best information available, extends 200 to 300 miles to sea. Numerous aerograph flights were made to points 30 to 40 miles west of San Diego, and also to the south, and the inversion was found to exist on all such occasions. On these flights, from altitudes of 8,000 to 12,000 feet, the characteristic clouds and haze could be seen to distances of more than 100 miles at sea, indicating that the inversion extended at least 100 miles or more to the west, southwest, and south. In February, 1929, the U. S. S. *Saratoga*, while en route from San Diego to Panama, experienced inversion weather well south along the California Peninsula. An aerograph flight 800 miles south of San Diego revealed a well formed inversion, and velo clouds covered the sky for another 200 miles. In June of the same year, while returning from Panama, the *Saratoga* passed under the characteristic velo cloud at about the same point off Lower California and continued under the same inversion conditions during the remainder of the trip to San Diego.

From all information obtained it seems safe to assume that during the summer the inversion ordinarily extends from southern Washington to a point 800 to 1,000 miles south of San Diego, west from the coast for a distance of 200 to 300 miles, and over the land areas between the ocean and the Coastal Range. This gives an area about 2,000 miles parallel to the coast, and about 250 to 350 miles west of the Coastal Range. Finding it difficult to explain an inversion over such an area, and with such different wind conditions, by the explanations given in the fourth paragraph (i. e., heated air from the inland and a settling of air from a HIGH in upper atmosphere) a more satisfactory explanation was sought. Upon consulting pilot charts it was found that the prevailing winds along the coast are from the northwest, covering a belt from Washington to Lower California, and about 200 to 300 miles to sea. Just to the west of the northwesterly wind belt there is a similar area with the prevailing winds from the north, and to the west of this, or beginning about 500 to 700 miles off the coast, the northeast trade winds are found and they continue to and beyond Hawaii. The characteristic weather of the northwesterly wind area is of the inversion type, and that of the trade winds in summer is of the instability shower type. What the characteristic weather is within the northerly wind belt was not determined. It was further found that the temperature of the water along the coast from Washington to Lower California is colder than that at a distance offshore, and that the water temperatures west of the San Diego-San Pedro area continue to rise to and beyond Hawaii. As would be expected, the temperatures fall to the north from San Diego and rise to the south, but the temperature changes along the coast, north and south, are not as great as the rise in an equal distance to sea, especially to the west and southwest. According to the Hydrographic Office Publication No. 84, Mexican and Central American Pilot, the warmest water of the eastern Pacific is found in the region 1,000 to 1,500 miles south and southwest of San Diego where the mean temperature in August is said to rise to 85 F.°, at times. The temperature of the sea water in the San Diego area at the same season is about 60° to 62°F. When it is remembered that during this same season the inversion is best developed, this fact becomes important.

The pressure gradients over southern California and the adjacent ocean are ordinarily very weak, especially in the summer, and the average surface winds correspondingly light. However, during the heated part of the day the sea breeze frequently attains a velocity of 12 to 18 knots, at least during the early part of the afternoon. It has been reported from observations taken on board some of our battleships while cruising west of San Clemente Island, which is about 60 miles offshore, that the winds in that district are frequently stronger than those nearer land. The reports referred to stated that the winds experienced were 18 to 25 knots, whereas a check showed that the winds along the shore on the days indicated were 10 to 15 knots. Ordinarily the

winds aloft are likewise moderate, but occasionally very high velocities occur.

As stated above, the prevailing direction of the surface wind along the eastern edge of the Pacific is northwesterly. Probably it would be more accurate to state that along the immediate coast the prevailing winds are from the northwest to west. Easterly surface winds seldom occur during the summer except under Santa Ana wind conditions.[3] Prevailing directions at 500 to 1,500 meters are also northwest, but above that height the prevailing direction is southwest. These statements have been made after examining a table published in an article, "Temperature Inversions at San Diego, as Deduced from Aerological Observations by Airplane," by Mr. Dean Blake, of the Weather Bureau office at San Diego in the MONTHLY WEATHER REVIEW, June, 1928. The conclusions drawn from this table by Mr. Blake are as follows:

> Even the most cursory examination forces us to draw several obvious conclusions, namely: (*a*) That at virtually every level, winds were from the ocean the larger percentage of the time; (*b*) that between 2,000 and 10,000 meters the percentages from the land and ocean remain fairly constant; (*c*) that beyond 10,000 meters the few soundings obtainable showed an increasing frequency from the ocean; (*d*) that the prevailing direction at all levels was southwest; (*e*) that the northwest currents believed to predominate at the higher levels, summer as well as winter, were not in evidence.

It is not understood how Mr. Blake derived the conclusion marked "(*d*)" for the table, based on pilot-balloon soundings for June, July, and August during the years 1924 to 1927, inclusive, as the naval air station, San Diego, clearly shows the preponderance of northwest and west winds at the surface, and northwest winds at 500 to 1,500 meters. Aside from this, the conclusions appear to be sound. Regarding the velocities of the winds, Mr. Blake states:

> Although a chart has not been prepared for the velocities during the same period, it was further observed that at the soundings under 2,500 meters they were rarely other than light, and when from the eastern, or land, quarter were more in the nature of a drift than a current.

These conclusions are believed to have been substantiated during the summers of 1928 and 1929, except at the times of Santa Ana winds when very high velocities were sometimes found.

Continuing in this article, Mr. Blake states:

> If we can make our deductions from four years' record, then there must be other causes for the steep inverted gradients besides an overflow of hot air to the coast from convectional action in the Imperial and Colorado Valleys, as inversions occurred at every observation regardless of wind direction.

It is believed that sufficient facts have now been presented to show this "other cause." It will be remembered that practically all of the air over the coastal region comes from the sea. Except immediately along the coast to the north, the water everywhere, within a distance of 1,000 miles, is warmer than at any given point along California. This means that air from any portion of the Pacific Ocean, while approaching the coast, must pass over colder and colder water, and especially is this true when the air moves from the south or southwest where the temperatures rise quite rapidly with distance offshore. The processes which takes place as warm air passes over the colder water are relatively simple. The first effect is the cooling of the surface air to the temperature of the water. Due to friction between the air and the water, especially where waves have formed, the lower layers of air become turbulent and are filled with eddy currents which mix the cooled air with the warmer air above it, each mass leaving the surface tending to cool adiabatically as it rises. At first the surface air is thrown upward into warmer and less dense air and considerable energy is required. This energy is furnished by the wind. After the process has continued for some time the temperature of the air in this stratum decreases rapidly with altitude, in time equaling the dry adiabatic lapse rate. Above this stratum the temperature increases for a greater or lesser distance, and then decreases at approximately the original rate. After the dry adiabatic lapse rate has been established near the surface it will not require as much energy to throw a mass of air from the surface to a given distance aloft as at the beginning, hence, assuming the same wind velocity, surface air will be thrown to a greater height. There is a limiting distance, however, for each wind velocity which will vary somewhat with conditions of temperature and humidity.

Although statements were made above showing the prevailing wind directions for the various areas along the coast, it is not to be assumed that such winds are constant. For instance, the table of Mr. Blake, which was prepared from the afternoon pilot balloon records and therefore show the conditions at that time of day, shows that the surface winds were from the northwest on about 40 per cent of the occasions, from the west about 30 per cent, and from the southwest about 25 per cent. This shows that it is perfectly possible for air to approach San Diego from any portion of the eastern Pacific. Should a mass of air with a normal lapse rate of 3° F. per 1,000 feet move from the very warm area to the south and southwest, where its surface temperature was 80° F., it would reach San Diego with a surface temperature of about 60° F. If clouds have not developed, its lapse rate from the surface to the base, assumed to be 1,500 feet, would be approximately equal to the dry adiabatic, and the temperature at the base would be about 8° F. lower than at the surface, or about 52° F. The temperature of the air above this point would increase from the minimum of 52° F. to some point, say 1,000 feet higher, where a maximum temperature would be found which, in this case, would be approximately 72° F. This mass of air would, therefore, reach the coast with a 20° inversion, and the maximum temperature at 2,500 feet would be 12° F. higher than that of the surface air just off the coast. This maximum temperature would also be at least as high as that of the surface air at the fleet air base, or San Diego, on the normal day. By following a mass of air from any other point of the eastern Pacific, except almost directly along the coast to the north, it will be seen that it will reach San Diego, or any other point on the California coast, with an inversion but, of course, less in amount as the source of the air is farther to the north. Many degrees of inversion have been recorded by the aerographs, ranging from no inversion to one of 29° F., also with maximum temperatures aloft less than the surface temperature, equal to it, and greater. While this thermal stratification of the lower atmosphere is being established, important humidity changes occur. Once the inversion is formed, the water vapor, both the original and that received from evaporation, is distributed in the stratum below the base by the turbulence, and in this way the moisture content of the lower stratum is increased, while above the base the amount of water vapor remains about the same as it was originally. The surface turbulence causes the relative humidity to increase rapidly from the surface to the base. This, with con-

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[3] Santa Ana wind or simply Santa Ana—A name given by Californians to a strong dessicating wind having a northerly component which under favorable pressure conditions blows through passes in the Santa Ana Mountains of southern California.

tinued evaporation, ultimately causes the dew point to be reached, following which clouds begin to form. Clouds and fog do not necessarily form early in this journey to the coast, both because the original air often does not have an especially high relative humidity, and also because the air does not come into contact with much colder water suddenly, as it does over the Grand Banks, in the Atlantic.

From what has been said above it appears that any mass of air approaching any point on the Pacific coast south of the State of Washington from a considerable distance at sea, except almost directly along the coast to the north, must develop an inversion very similar in characteristics to those observed day after day in the San Diego area.

Although both the surface and upper winds carry air from the sea to the land by far the greater percentage of time, still on some occasions there is a definite air flow from the land. A well formed Santa Ana wind represents the maximum development of such conditions. Santa Ana winds are caused by high pressure areas over the Central Plateau region with relatively low pressure off lower California. Such a pressure distribution causes air to flow from well inland to the coast as northeast winds. In approaching the coast the air descends from the plateaus and mountains to the sea level and is heated both adiabatically and by the highly heated valleys over which it passes. At times the winds at the surface reach, or exceed, gale force, while very high velocities frequently occur aloft. This air reaches the coast very hot and dry, and with considerably less density than that adjacent to the surface of the ocean, so it is forced to rise from the surface soon after passing the coast line. An exceptionally good illustration of this occurred during the summer of 1929 when a Santa Ana of more than usual intensity caused northeast surface winds with gusts exceeding 35 miles per hour at North Island, and caused such heavy clouds of dust that flying was discontinued during the afternoon. During this time the U. S. S. *Aroostook* was conducting exercises at sea, about 10 to 15 miles southwest of the naval air station. At no time did the *Aroostook* encounter northeasterly winds, but was in light westerly winds during the whole afternoon. The Santa Ana winds continued the next day but with considerably less velocity, no gusts exceeding 30 miles per hour having been recorded. At the time of these maximum gusts a large bombing and torpedo plane (*T4M*) took off to calibrate altimeters at 6,000 feet. The pilot gained the desired altitude at a point about 4 to 6 miles southwest of North Island and, upon signal, leveled off, but instead of remaining at 6,000 feet the plane continued to ascend to 6,900 feet regardless of the fact that the pilot was attempting to stop the rise. Before reaching the maximum altitude the pilot turned to the observer and indicated his inability to maintain the desired level. Although the cause for the strong ascending currents was not fully recognized at the time, another attempt was made farther at sea and the proper altitude was maintained for five minutes without difficulty. No reports were received from the surface craft on that day, but it seems safe to assume that the northeast winds did not remain at the surface for a greater distance than 4 or 5 miles after crossing the shore line. Through conversation with aviators and officers of the Battle Fleet, other instances have been learned of where vessels have experienced normal conditions within 15 to 20 miles of the shore at times when strong Santa Ana winds were reported at near-by ports. However, that the strong northeast winds frequently proceed hundreds of miles to sea in the upper levels is proved by reports of dust clouds and sand storms by ships several hundred miles at sea.

During the summer of 1929 aerograph flights were made both during and immediately following several Santa Ana winds. As would be expected it was found that the temperatures, both at the surface and aloft, were much above normal, and that the relative humidity, very low at the surface, approached 0 per cent aloft. As soon as the intensity of the Santa Ana decreased sufficiently to allow the sea breeze to be reestablished over the coast it was found that the characteristics of the stratum below the base had changed little, if any, from the normal, but aloft the high temperatures and very low humidities continued for several days.

The above paragraphs show the principal characteristics of inland and ocean air approaching the coast, that from land being hotter and much drier than that from sea. Just as Santa Ana winds are of rare occasion, so are winds of the solid current type from sea, for, as stated above, the pressure gradients are generally very weak over that portion of the sea during the summer. A special chart was prepared to study the inversion conditions on which all pilot-balloon soundings made at the naval air station during the latter part of the summer of 1929 were entered by means of arrows, flying with the wind, at the various altitudes. Red arrows represented easterly or land winds, and blue represented winds from the ocean. A study of this chart gave the impression that at times the air along the coast line frequently drifts inland for a day or two and then drifts to sea, or vice versa. This chart was not started until late in the investigation, and owing to other duties there was no opportunity to study it as fully as desired. The most interesting features noticed were that with a slow drift from land the upper air temperatures rose and relative humidity fell, while in apparently the same air drifting back from sea a day or two later the temperatures had fallen and the relative humidity had risen somewhat.

The main points brought out in the foregoing paragraphs are as follows:

(*a*) By far the greater portion of air reaching the California coast both at the surface and aloft, comes from the ocean.

(*b*) Air reaching the California coast from practically any part of the Pacific Ocean will have developed an inversion by the time the coast is reached. This air will have a considerable amount of moisture in the warm air above the base.

(*c*) When air flows over the coast and adjacent ocean from well inland it causes a larger inversion than is caused by air from the sea, and the amount of moisture above the base is very small.

(*d*) The upper air over the coastal waters and adjacent land is ordinarily a mixture of air from various areas, sometimes a mixture of inland and ocean air, but more often a mixture of air from various regions over the ocean. The inversions which occur under these conditions have characteristics intermediate between those of (*b*) and (*c*).

Velo clouds form in the moist stratum of air below the base as a result of processes to be described in a later paragraph. If the temperature of the surface air is considerably above that of the water toward which it is moving, or if it is highly humid before the cold water is reached, low clouds, or fog, will form far at sea and move landward with the air mass. This is especially true in the case of air from the south and southwest. On the other hand, if the temperature of the air approaching the

colder water is only slightly higher than that of the water along the coast, or if its vapor content is relatively small, it may reach the coast with a well-developed inversion without either clouds or fog. However, if this air continues in contact with the ocean for any considerable length of time clouds will ultimately develop, because evaporation constantly adds water vapor to the lower stratum, and turbulence distributes it. It was stated that the turbulence in the lower atmosphere causes the cooling of air below the base and that this cooling might, in time, cause clouds. Solar radiation, however, opposes this and is the controlling influence most of the time during the day. A much more effective cause for cloud formation is found at night when radiation from the top portion of the moist stratum causes the already cold air just below the base to become colder. This, ultimately, results in instability, and any further cooling will cause convection. Obviously, these processes are operative throughout the night and the dew point will ultimately be reached. This accounts for the fact that the velo cloud forms only during the latter part of the afternoon or at night, and burns off during the next day.

Velo clouds always develop in the lower stratum where evaporation, turbulence, and convection are operative. So far as has been learned there always is an inversion above the cloud sheet; there certainly was on all occasions when observations were made in 1928 and 1929. Although these clouds are not formed by an inversion, but by the conditions in the stratum below the inversion, it does have a marked influence on them after they are formed. The height of the base is, in many cases, the determining factor as to whether the condensation will result in clouds or fog. The rate of increase in temperature above the base, and the amount of water vapor present, determine whether or not the altitude of the base will remain the same, or whether it will rise after condensation begins. This has a very definite influence on the height of the cloud sheet, its thickness, and whether or not it will develop downward to the surface. It is this lifting of the base through convection and condensation that causes a new mass of air from the south or southwest to so often produce fog at first and later only velo cloud.

It is believed that the "more satisfactory" explanation of the inversion, sought in an earlier paragraph, has been found, namely, that the inversion is a sea condition and is caused by the cold water along the coast. It explains why the inversion extends so far to the north and south and such a short distance east and west. It explains also why the inversion exists with deep westerly winds as well as winds from shore, and under pressure conditions which almost positively preclude the subsidence theory. Accepting the theory that the velo cloud is caused by thermal convections opens the way to understand some of the peculiar habits of the inversion and the base. It also explains some of the most interesting types of the irregular weather and, it is believed, it puts a very useful instrument into the hands of the forecaster who is compelled to answer the whens, the whys, and the how much.

The following paragraphs deal more directly with the observations made at San Diego during 1929, telling how the flights were made, what special conditions were observed, and how certain observations tend to substantiate the foregoing explanations regarding the inversion and the velo cloud.

Practically all of the flights were made in a seaplane, or an amphibian plane, over the ocean, and the air explored with a standard Friez aerograph attached to the outer portion of the right wing. During the period of these flights, aerological flights with the same type of aerograph were being made at the naval air station, San Diego, in a landplane which generally flew inland. At times it was arranged so that special flights were made to sea and inland simultaneously, and the records compared. Always on such flights the planes made one or more descents to cut the inversion at various places. At first considerable difficulty was encountered with the relative humidity element on the aerograph carried by the seaplane, and the records could be accepted only in a general way. Later new hairs were installed and thereafter the readings were considered as trustworthy as those on similar instruments.

Great effort was made to obtain correct readings on all flights. It had been noticed that the temperature traces on the records were frequently inaccurate at the take-off, owing to solar radiation, exhaust engine gases, etc. These records had led to the belief that the lapse rate from the surface to the base often greatly exceeded the dry adiabatic lapse rate, but flights made according to the adopted plan of having the correct temperature of the surface air before the take-off, and then rising very slowly, practically never showed a superadiabatic lapse rate, except for very limited distances. However, the true lapse rate was ordinarily found to equal, or closely approximate, the dry adiabatic. Close observations of the relative humidity pen during flight led to the belief that many of the older humidity records were erroneous, due to the rate of climb and the lag of the humidity element, and showed a rate of fall in the relative humidity above the base greatly in excess of the actual decrease. By rising very slowly and leveling off frequently, it was found that while the relative humidity does fall rapidly it does not usually fall as rapidly as believed from the old records, except where the upper air has come from well inland. In addition to the specific instances given, much time was spent flying along the base, and in and around forming and dissipating clouds. Special conditions were watched for and, when found, flights were made according to the plan which seemed best suited to determine the actual conditions.

The inversion is known to have covered the San Diego-San Pedro area not only on the days of these special flights, but on practically every other day during the summers and autumns of 1928 and 1929.

Careful observations, and aerograph records, during many flights showed that the top of the velo cloud almost always coincides with the base. When clouds are not present the base may be identified by the top of the moist surface stratum which, when viewed from above, has a milky appearance and is characterized by indifferent to very poor visibility near its top. Above the base the air is clear and the visibility good. The surface separating these air masses is so sharply defined a pilot may easily fly with the lower part of the plane in the moist stratum and the top part in the warm air above.

The inversion was identified on these special flights to points 30 to 40 miles south, southwest, west, and west-northwest of San Diego, and inland to the foothills and mountains, by means of the aerograph. On many of these days it was identified by means of the velo cloud and haze layer to points more than 100 miles to sea. The U. S. S. *Lexington*, en route from Honolulu to San Diego in June, 1928, passed under the velo cloud at a point about 200 miles off San Diego. This cloud sheet continued unbroken to the coast. The clouds were absent and the weather conditions entirely different at a point 360 miles offshore.

The top of the well formed velo cloud, and also of the haze layer, is remarkably level over the sea. Both are higher over land during the day, due partly to the contour of the country and partly, no doubt, to the thermal conditions. Little difference could be found in the height of the base a short distance offshore and 30 to 40 miles at sea, although great care was taken in these determinations since it was, and is, believed that the surface stratum is wedge shaped and that the inversion is much lower, and of considerably less magnitude, at a distance of 100 to 150 miles to the west. Several records definitely showed a smaller inversion 30 to 40 miles at sea than a few miles offshore, and a few were believed to show a lower altitude, but the difference was so small the records were not considered conclusive. The heights of the base were always obtained from records made during slow ascent, since it had been found early in this investigation that aerograph readings made during ascent should not be compared with those obtained on descent.

As was to have been expected, it was found that the amount and sharpness of the inversion was less over land than over sea during the day, and that both of these conditions decreased with distance inland.

Many flights were made to determine the lapse rate from the surface to the base in clear weather. On these flights the plane was allowed to remain on the water with the aerograph on the windward wing and in the shade of the upper wing until the temperature trace was steady. This was done to insure that the true air temperature was recorded at the take-off. To overcome instrumental lag, the ascent to the base was made very slowly, as much as 30 minutes having been required to climb 2,000 to 2,500 feet on several occasions. All records obtained during flights of this type show a lapse rate equal to, or closely approximating, the dry adiabatic lapse rate. In a few instances a superadiabatic lapse rate was found for short distances. These flights also showed a gradual increase in relative humidity from the surface to the base. Several theoretical humidity curves were prepared from the Neuhoff Chart for comparison with individual aerograph records. To obtain this curve the current surface humidity was taken and, assuming that the moisture had been thoroughly distributed by turbulence, points were picked off the chart in accordance with the temperatures found at the various altitudes. On some flights the relative humidity traces showed that the water vapor had not been thoroughly distributed, and in every instance the sky remained clear until late at night, although on several occasions clouds began forming in late afternoon, but soon dissipated.

The impression had been gained from many records that the relative humidity fell off very rapidly above the base. In nearly every case where the plane climbed very slowly into the inversion it was found that this falling off in relative humidity is considerably more gradual than had been anticipated, i. e., because of the sluggishness in the instruments, the lower strata above the base had been given credit with a degree of dryness which ordinarily does not exist. This, of course, is what would have been expected had it been known that the velo cloud is caused by convection.

The velo cloud occurs at sea far more frequently than over land, or even along the coast. Observations from planes have shown that, toward the end of a period of clear weather, clouds form far at sea, at least 50 to 100 miles, and spread eastward. It is not unusual to observe a well formed sheet, or bank, of velo cloud far beyond San Clemente Island, 60 miles distant, a day or two before clouds form over, or near, the shore. During normal summer weather,when the days are clear and the nights cloudy, the clouds begin forming over the sea several hours before any develop over land. On many of the brightest days on shore a cloud bank covers the ocean from a point a few miles offshore to a distance of more than 100 miles.

The first indication of the formation of the velo cloud is the appearance of innumerable cloudlets in the topmost part of the moist stratum. When viewed from above these cloudlets resemble little puffballs. They increase rapidly in number and size, merging with one and another, until large globular masses of clouds are formed. These clouds also increase in size and finally merge to form the velo cloud sheet. Observations of the above conditions have been made repeatedly from planes flying along the base. When watched from this level it is seen that the formation of the cloudlets is preceded by the appearance of little lumps on the top of the moist stratum, or haze layer, which, up to this time, has been remarkably smooth and level. In a short time small cloudlets can be seen forming in the lumps and as the plane flies along the base a marked increase in bumpiness can be noticed as it passes through that area. After the cloudlets have grown into the globular masses of clouds, mentioned above, well defined ascending currents can be noticed when flying through them.

The above observations, of course, suggest convection. Although the thermal conditions have been shown to be favorable for convection during late afternoon and night, a more positive confirmation of the idea is found from the fact that, in nearly all of the cases observed, the base rose over the forming clouds, i. e., the cold, moist air rose into the warm air above. This could easily be observed from the milky appearance of the moist air as well as by the clouds themselves. Under certain favorable conditions, namely, when the temperature increased but slowly with altitude above the base, and there was a fair amount of moisture in the warm air, the base was found to be 300 feet higher over a mass of forming clouds than in the surrounding clear areas. Under similar conditions the top of a well formed sheet of velo cloud was observed to rise 300 feet in 5 minutes and another 200 feet during the next 15 or 20 minutes. This observation was made in the late afternoon when the bank was approaching the shore. The base sloped downward from the top of the clouds, which were more than 1,200 feet in depth, to the original base along the coast. Clouds were developing rapidly under the sloping portion of the base, being in the form of small puffballs near the shore, globular masses a little farther at sea, and columns near the edge of the bank.

Some aerograph records show a very rapid rise in temperature and a very rapid decrease in relative humidity above the base. The Neuhoff Chart shows that the base can not rise to any extent under these conditions even though the cloud sheet attains considerable thickness. Since radiation from the top of the moist layer must continue, whether the base rises or remains the same, the convection will continue and, instead of the top of the clouds becoming higher, the base of the sheet will become lower. Many flights have shown the height of the base in the morning to be approximately the same as during the preceding afternoon, and it is not uncommon to observe a very low cloud base in the early morning. There is a peculiar fog condition which occasionally results from the lowering of the cloud base. This condition has been carefully watched in San Diego where the

base of the clouds could be seen to become lower until it obscured the tops of the high buildings, then the lower buildings, and finally rested on the surface and appeared in all respects like true fog. As this occurred at night it was possible to see the base of the cloud as it approached the street lights, and it was observed to be very irregular and ill-defined. Such fogs generally do not last more than two or three hours. When they clear they sometimes do so from the bottom up and again from the top down, i. e., in the former the cloud clears at the surface but continues aloft, while in the latter the top either clears, or descends, until the surface is reached and the sky remains clear the remainder of the night. The latter condition was observed more frequently than the former. If a sharp base is known to be at 1,000 or 1,200 feet, or less, and the relative humidity at the surface somewhat above normal, fog is to be expected that night.

It hardly seems necessary to mention that the presence of a considerable amount of high clouds, either cirro or alto clouds, greatly retards the forming and burning off of the velo cloud. However, this is a fact and must be considered by the forecaster when attempting to answer some of the whens he is asked.

The flights and observations described above were made largely because of the belief that if the inversion and the velo cloud were more fully understood, the explanation of the various types of weather would follow. Although it was impossible to verify many of the following contentions, it is believed that the principles set forth in the preceding paragraphs satisfactorily explain many of the perplexing questions which confront the forecaster along the California coast. Among the most important of these may be mentioned (*a*) the existence of the inversion with deep westerly winds as well as with winds from land; (*b*) why the velo cloud forms; (*c*) why it is typically a night cloud; (*d*) why it occurs over the ocean so much more frequently than over the land; (*e*) why it frequently does not burn off at sea; (*f*) why the base frequently rises during the night; (*g*) why the cloudiness sometimes increases for several days and then decreases during the next several days (occasionally the clouds will disappear entirely within 24 to 48 hours and the resulting clear weather will continue for several days); (*h*) why fog is almost sure to develop along the coast and for several miles inland on nights when the base is less than 1,200 feet high, especially when the temperature above the base increases rapidly; (*i*) why this type of fog clears over the land within a few hours, sometimes from the ground up, but more often "from the top down"; and why a light mist sometimes falls in the early morning during the summer.

It is recognized that the observations made in 1929 are but the beginning of those necessary to solve the riddle of the irregularities of California's regular weather, but it is felt that useful, as well as interesting, information has been obtained. It is seen that the aerograph has become much more helpful to the forecaster because, by means of it, he is supplied with such very useful information, as, the height of the base, the amount and sharpness of the inversion, the humidity above the base, and the lapse rate and distribution of moisture below the base. All of these data are of practical value in forecasting local weather and, in all probability, will become more so as additional facts are learned since, even with the imperfect ideas held during this investigation, the thickness of the morning velo cloud and the height of the base were forecast several times from the afternoon aerograph record and the Neuhoff chart. It is granted that this was largely the result of chance, since the assumptions made were only guesses. Still there appear to be no good reasons why, with additional knowledge, not only the height and thickness of the clouds and the height of the base, but also the other features which are of vital importance to the aviator and navigator will be forecast with confidence and accuracy.

SOUTHERN ARIZONA FLYING WEATHER

By Leon C. Walton

[Weather Bureau Office, Phoenix, Ariz.]

Science and invention have accomplished considerable in recent years to further the cause of aviation. Equipment has been improved and many valuable lessons learned, often at great cost, so that aerial navigation has been stripped of most of its perils. In flying circles, the weather remains a favorite topic but even that has been shorn of its terror, not because we can defy or control the elements, but due to the excellent system of reporting and forecasting conditions as they are and as they will be a few hours or days hence.

No section of the country enjoys "perfect" weather, but southern Arizona is probably as free from weather hazards as is any locality in the United States.

The route selected by the Southern Transcontinental Airline from El Paso, Tex., via Douglas, Tucson, and Phoenix, Ariz., to Los Angeles, Calif., traverses a flat open terrain, with the exception of a low range of mountains near the Arizona-New Mexico boundary, and a scattering of hills, some of which have been dignified by the name of "mountain." Throughout the greater portion of the year, a pilot flying over this territory at an altitude exceeding 1,500 feet is in a realm where the visibility is limited only by the power of his own eye. Haze, smoke, fog, low clouds, and other limiting agents are of such rare occurrence as to be almost negligible. Snow, sleet, and ice are practically unknown, and the only place they could occur would be in the upper reaches over the only range of mountains crossed.

Dense fog, so feared in many localities, seldom obscures the Arizona landscape. It has been observed only 36 times in the past twenty years at the Phoenix Weather Bureau office, and the distribution by months leaves most of the year fog free. December leads with 20; January follows with 11; November supplies 4; and March furnishes the other day with dense fog. Five of the twenty years have had none at all. During the winter months an occasional blanket of smoke partially obscures the city of Phoenix but leaves the airport clear. At Douglas, Ariz., the smoke occasionally cuts the visibility to as little as 3 miles, but is never dense enough to offer a serious handicap to flying, as the "blanket" is not more than 300 or 400 feet in thickness.

Another indication of the excellent visibility is the fact that the beacons between Phoenix and Los Angeles are located about 30 miles apart. East of Phoenix the airway is not yet lighted but when installation is completed the average distance between beacons from Dallas to Los Angeles will be as nearly uniform as possible.

Ceilings are usually unlimited, or at least, sufficient to allow a generous margin of safety. In time of precipi-

tation estimated ceilings less than 1,000 feet have been reported, but the lowest ceiling encountered by a pilot balloon is 1,125 meters, or 3,700 feet.

With fair weather the prevailing condition, flight schedules are seldom interfered with. Occasional unfavorable weather at the coast terminal delays a plane's departure, but cancellations are few. During the eight months of airmail in this section, only about 15 flights have been canceled due to Arizona weather, most of these occurring during February of this year.

In line with its policy of cooperation and expansion, the Weather Bureau inaugurated pilot balloon work at the Phoenix Weather Bureau office in February, 1930, and the data thus obtained played an important rôle in preparing schedules for the air mail which began eight months later.

The upper-air data herewith presented have been prepared from the results of the first year's observations, i. e., to January 31, 1931. Only the regular morning and evening runs have been considered, of which there have been 696 out of a possible 708, or 98.3 per cent. Only 5 of the 12 runs omitted were missed on account of the weather. Surface data are not included in the accompanying tables, being deemed of insufficient value to justify the time necessary for its preparation. The surface wind at the morning observation is light to gentle easterly with surprising regularity, while that at the afternoon run is usually light to gentle variable. The exceptions to both of these generalities would not be sufficient to affect the averages. Four levels have been selected for study, namely: 1,000, 2,000, 3,000, 4,000 meters above sea-level, and it is interesting to note that these levels were reached by 696, 694, 624, and 446 balloons, respectively. Thus, only 70 runs failed to supply data as high as the 3,000 meter level. The large decrease between the 3,000 and 4,000 meter levels is caused by the use of lanterns for the morning observations.

TABLE 1.—*1,000 meters above sea level*

[Velocities in meters per second; fractions omitted]

	Summer				Winter			
	A. M.		P. M.		A. M.		P. M.	
	Number	Average velocity	Number	Average velocity	Number	Average velocity	Number	Average velocity
N	11	2	2	3	7	4	5	2
NNE	2	4	5	2	7	5	4	4
NE	7	3	3	3	10	4	6	2
ENE	7	4	0	0	32	6	6	4
E	8	3	0	0	22	7	14	4
ESE	13	6	7	2	20	6	20	5
SE	9	6	8	4	7	4	7	5
SSE	6	4	4	5	3	5	6	2
S	7	6	5	3	6	8	9	5
SSW	7	3	7	4	7	3	7	7
SW	8	6	13	3	14	4	12	4
WSW	27	5	36	5	6	3	16	4
W	30	4	47	5	12	5	20	5
WNW	15	5	27	4	4	3	18	5
NW	11	4	10	3	3	13	6	3
NNW	9	3	3	2	4	3	7	3

The following tables, numbered 1, 2, 3, and 4, present the results of these 696 observations. The division into summer and winter include April 1 to September 30, and October 1 to March 31, respectively. The first column under each season gives the total number of times the wind blew from the directions indicated regardless of velocity. Otherwise the various headings are self-explanatory. Originally, it was planned to include the wind resultants for each season, but as these data are already on file, by months, at the Weather Bureau offices in both Washington, D. C., and Phoenix, Ariz., available to those who may have special need thereof, this plan was abandoned in favor of the less technical one presented in this paper.

TABLE 2.—*2,000 meters above sea level*

[Velocities in meters per second; fractions omitted]

	Summer				Winter			
	A. M.		P. M.		A. M.		P. M.	
	Number	Average velocity	Number	Average velocity	Number	Average velocity	Number	Average velocity
N	7	2	3	4	11	4	13	6
NNE	6	2	2	2	7	7	11	6
NE	2	2	2	2	6	5	11	7
ENE	5	3	7	3	14	5	13	6
E	8	4	5	2	11	6	13	8
ESE	7	4	6	4	17	6	12	7
SE	10	5	4	4	10	6	3	5
SSE	8	6	9	5	6	8	8	5
S	24	7	17	7	7	7	9	8
SSW	15	7	24	6	10	7	15	6
SW	17	5	23	6	20	5	10	8
WSW	19	6	25	6	9	8	11	7
W	15	4	21	5	7	8	11	7
WNW	14	4	15	5	9	6	8	7
NW	11	5	6	4	14	6	7	5
NNW	8	2	4	5	8	5	9	5

TABLE 3.—*3,000 meters above sea level*

[Velocities in meters per second; fractions omitted]

	Summer				Winter			
	A. M.		P. M.		A. M.		P. M.	
	Number	Average velocity	Number	Average velocity	Number	Average velocity	Number	Average velocity
N	7	5	5	5	8	10	14	11
NNE	6	4	3	4	2	6	12	7
NE	2	4	6	4	7	7	7	5
ENE	2	2	5	3	9	7	13	8
E	5	6	6	4	6	7	12	9
ESE	6	7	8	6	6	6	5	10
SE	4	3	7	4	4	5	5	7
SSE	8	5	13	6	4	6	6	7
S	27	9	18	9	7	10	7	8
SSW	28	9	24	9	6	8	9	11
SW	21	9	34	9	20	9	11	9
WSW	16	10	32	7	10	7	12	11
W	9	4	20	6	13	9	4	9
WNW	2	4	9	4	7	8	14	8
NW	6	5	7	7	12	8	7	9
NNW	3	5	7	4	18	8	14	9

Referring to Table 1, it will be noted that during the summer, the prevailing direction is west, or points immediately adjacent thereto, and in the case of the morning observations, is in striking contrast to surface winds. Experience has shown that these surface easterlies are very shallow, the balloons frequently encountering opposing or cross currents a few seconds after being released. During the winter, this lower stratum of westbound atmosphere is somewhat thicker, extending to the 1,000-meter level with greater frequency. In the afternoon, throughout the year, the western quadrant supplies the greater portion of the winds. The range in velocities is small, so the averages listed are truly representative.

Inspection of Table 2, reveals the fact that the prevailing easterlies in the previous level are caused by conditions more local than general, as their influence apparently barely extends to the 2,000-meter level. That they

are more prevalent in the winter than in the summer would indicate that the temperature is vitally important in their existence. In this higher level we find southwest predominating, although the range is from south to west. This is especially true in the summer, as in the winter the winds are more variable. Velocities are higher and, although the increase is not great in summer, there is a tendency toward stronger winds, particularly in the cooler months of the year.

TABLE 4.—*4,000 meters above sea level*

[Velocities in meters per second; fractions omitted]

	Summer				Winter			
	A. M.		P. M.		A. M.		P. M.	
	Number	Average velocity	Number	Average velocity	Number	Average velocity	Number	Average velocity
N	3	7	9	3	3	7	17	9
NNE	3	10	6	5	3	3	4	11
NE	1	3	4	8	11	7	5	8
ENE	2	6	3	3	2	8	12	9
E	3	6	1	11	0	0	5	8
ESE	2	2	6	6	2	3	3	7
SE	3	4	4	4	0	0	4	4
SSE	5	6	9	5	3	7	2	6
S	5	9	11	10	0	0	6	6
SSW	14	12	16	11	0	0	8	9
SW	14	10	29	9	5	12	10	10
WSW	13	10	26	10	4	15	16	12
W	6	8	14	8	5	19	4	14
WNW	5	7	12	6	5	8	16	10
NW	4	5	4	6	11	14	12	14
NNW	2	6	10	3	8	12	10	15

The conditions found at 2,000 meters extend upward through the other two levels, with an ever improving advantage to the eastbound flier. During the summer the sector south to west prevails, while during winter, the directions are from west to north.

Briefly, then, the fact that Phoenix has a greater number of easterly surface winds does not indicate that the upper currents differ from those over the country in general. On the contrary, we find that the movement is from the western portion of the compass. However, the upper winds cover a wider range of directions than are found to exist in many sections of the United States. This may be due to the location of Phoenix at a point considerably south of the usual paths of the cyclones and anticyclones.

Upper-air investigation has revealed several interesting features of the atmosphere in this region. Surface winds are usually light, and, particularly on hot afternoons, this "stagnation" often extends to considerable altitude. Balloons have been followed to 4,000 meters and 5,000 meters with elevation angles remaining above 60°. Graphs of such runs show every point of the compass.

Estimating ceiling or cloud height.—Most observers learn to associate cloud formations with altitudes, so when one is known, the other can be more readily estimated. Such individuals face a problem in this locality until the acquisition of sufficient data warrants definite estimates. Of the 1,150 balloon runs made to date, cloud altitudes have been ascertained in exactly 100 instances, but these, with 3 exceptions have been confined to 3 cloud types. Strato-cumulus lead in frequency, ranging in altitude above the surface from 1,100 to 4,200 meters, with an average of 2,250 meters. The two remaining types share equally as to frequency but show considerable variation in altitude. Alto-cumulus range from 2,400 to 6,400 meters with an average of 3,700 meters, as compared with an average of 5,400 meters for alto-stratus, which showed a range from 4,000 to 8,000 meters. Comparison with the cloud altitude charts in common use indicates that clouds in southern Arizona average somewhat higher than in other portions of the country.

Everything considered, flying conditions are very favorable in this section. An average of only 41 cloudy days, 39 of which with a measureable amount of precipitation, per year; no ice-forming weather; no snow; very little fog; and very few high winds, 43 miles per hour being a 35-year maximum, are some of the outstanding reasons why this has been designated "the fair weather route." Add to this the favorable upper winds as outlined above, and this locality's desirability as a flying center can be readily appreciated.

DIMINISHING WINTER RADIATION FROM SUN AND SKY AT MADISON, WIS.

By ERIC R. MILLER

[Weather Bureau, Madison, Wis.]

A continuing decrease of the insolation registered at Madison with the Callendar bolometric sunshine recorder was pointed out by Mr. A. F. Piippo (*1*) and the question whether it was due to city smoke or to deterioration of the apparatus was considered by Dr. H. H. Kimball in a note to the same paper. The present paper adds further data and applies statistical methods to their interpretation.

Smokiness in Madison is mostly due to heating, since the city is administrative, educational, and residential rather than industrial. The few industrial plants are located 3 or 4 miles east of the Weather Bureau station, and the prevailing winds are northwest in winter, southwest in summer. The university heating plant with chimney 250 feet high is 1,000 feet south-southwest of the station. Its annual consumption of coal (in tons of 2,000 pounds) in years ending June 30, was:

	Tons		Tons
1912–13	19, 576	1922–23	20, 649
1913–14	20, 489	1923–24	21, 693
1914–15	19, 640	1924–25	21, 076
1915–16	20, 039	1925–26	24, 773
1916–17	22, 986	1926–27	25, 963
1917–18	18, 670	1927–28	28, 463
1918–19	22, 162	1928–29	30, 554
1919–20	20, 429	1929–30	30, 153
1920–21	19, 183	1930–31	29, 446
1921–22	19, 997		

The smoke from this chimney always drifts off in a compact stream before diffusing. The proportion of black smoke has been greatly decreased in recent years by improvements in the furnaces to bring about complete combustion. It is not possible to present similar statistics of the use of coal for domestic heating. A notion of the change is afforded by the census reports of the population

of the tenth ward, which includes the western part of the city beyond the university:

1910	1, 092
1920	3, 664
1930	9, 590

When the sunshine record was begun, anthracite was largely used for house heating. Since then there has been a shift to bituminous and to oil.

Winter being the season of smoke emission, the data from the Callendar sunshine recorder have been separated as follows:

Calories per square centimeter of horizontal surface

December-March	Calories	June-September	Calories	Year	Calories
1911-12	29, 473	1911	58, 025	1911	125, 267
1912-13	26, 267	1912	55, 895	1912	122, 855
1913-14	24, 189	1913	57, 974	1913	122, 818
1914-15	26, 253	1914	57, 808	1914	123, 777
1915-16	25, 200	1915	50, 191	1915	114, 087
1916-17	28, 753	1916	58, 547	1916	125, 072
1917-18	28, 763	1917	55, 167	1917	122, 092
1918-19	23, 240	1918	55, 825	1918	120, 593
1919-20	26, 490	1919	56, 060	1919	116, 857
1920-21	21, 009	1920	56, 949	1920	121, 618
1921-22	25, 004	1921	57, 239	1921	116, 286
1922-23	25, 437	1922	55, 847	1922	118, 434
1923-24	22, 948	1923	52, 638	1923	118, 197
1924-25	23, 814	1924	51, 652	1924	112, 606
1925-26	23, 002	1925	56, 376	1925	119, 234
1926-27	23, 026	1926	52, 542	1926	115, 486
1927-28	25, 629	1927	56, 583	1927	112, 552
1928-29	23, 319	1928	54, 688	1928	119, 015
1929-30	23, 829	1929	56, 009	1929	117, 161
1930-31	21, 525	1930	57, 757	1930	120, 136
Mean	24, 858		55, 689		119, 207

The secular trend of each of these series has been found by fitting regression lines, using the method described by Persons (2), pages 158–160. These equations, in which the coefficient is the rate of change in calories per year, are:

		Per cent per annum	Per cent in 20 years
December-March	$y=-244.3x$	−0.982	−19.64
June-September	$y=-77.4x$	−0.139	−2.78
Year	$y=-391.4x$	−.329	−6.58

Of the annual decrease, 62 per cent occurs in the 4 months December-March.

The method of testing the significance of regression coefficients due to "Student" (3), pages 115–124, has been applied to these data with the following results:

	Std. error	t	P.
December-March	73.5	3.32	<0.01
June-September	90.3	.86	.40

where P. is the probability that a random sample will have a value of t falling outside the value found here. The regression coefficient for the summer months is evidently not significant, while that for the winter is highly significant.

Such a change could be brought about by an increase of cloudiness. Eye observations of the cloudiness during daylight hours have been made at Madison (bihourly since September, 1918), and the secular trend of cloudiness is shown by the following:

		Per cent per annum	Per cent in 20 years
December-March	$y=-0.0098x$	−0.151	−3.02
June-September	$y=-0.2.64x$	−0.489	−9.78

The observed trend of cloudiness is just the opposite of what is required to explain the decrease in the observed radiation.

However, it must be remembered that smoke, haze, and fog are excluded in making the estimate of cloudiness, hence an increase in smokiness should produce a decrease in the recorded cloudiness to the extent that clouds are obscured by smoke.

The hours of bright sunshine, registered by the thermometric sunshine recorder in the same 20 years, show the secular trend indicated by the following equations:

		Per cent per annum	Per cent in 20 years
December-March	$y=-5.05x$	−0.906	−18.12
June-September	$y=-.0069x$	−.00428	−.09

The percentage change of these data for December–March, agrees remarkably closely with the change in calories. The coefficient of correlation between calories and hours of sunshine for December–March is 0.75, which is less than would be expected from the similarity of secular trends.

Deterioration of the Callendar apparatus is believed by Doctor Kimball (1) page 504, to be indicated by the comparisons that have been made between the Callendar apparatus and the Marvin pyrheliometer. Since the Callendar apparatus registers the vertical component of sun and sky radiation, while the Marvin instrument is exposed normally to the sun's rays, the comparisons are made by shading the Callendar receiver, and reducing the drop in ordinate, trigonometrically. In series of observations made in 1913–1915 and in 1917 the shading of the Callendar instrument was simultaneous with the observations with the Marvin pyrheliometer, with the result that the trace of the recorder had to be interpolated. In 1927, the relatively smooth base line representing sky radiation only, was obtained by shading the Callendar apparatus before and after the pyrheliometer readings. This change of technique introduces some uncertainty into the comparisons. The results obtained vary with the altitude of the sun, so that there is either a variation of sensitiveness of one or other of the two instruments, or the trigonometric relations are not as assumed.

Results of comparisons to the end of March, 1927, were given by Doctor Kimball in the paper referred to. Some 37 additional comparisons were made in 1927. The following tables include all of the comparisons:

Number of comparative observations in each group

1913–1915	15	16	14	3	2	2
1917	10	7	5	4		
1927	10	31	24	14	5	1

Average solar altitude of each group

1913–1915	58.3	43.0	29.8	20.1	15.9	14.3
1917	60.6	43.6	30.2	21.7		
1927	55.7	41.5	30.5	22.1	16.5	12.6

Average factor (f.) to reduce Callendar to Marvin

1913–1915	0.0346	0.0342	0.0354	0.0380	0.0423	0.0502
1917	.0353	.0354	.0377	.0371	-------	-------
1927	.0354	.0356	.0358	.0381	.0418	.0489

Standard deviation of the observations of f.

1913–1915	0.0010	0.0018	0.0018	0.0024	0.0017	0.0015
1917	.0011	.0010	.0019	.0038	-------	-------
1927	.0020	.0013	.0023	.0031	.0051	-------

Standard error of the mean f. in each group

1913–1915	0.0003	0.0005	0.0005	0.0017	0.0017	0.0015
1917	.0004	.0004	.0010	.0022	-------	-------
1927	.0007	.0002	.0005	.0008	.0026	-------

Increase of f.

1913–1915 to 1917	*0.0007*	0.0012	0.0023	0.0009	-------	-------
1913–1915 to 1927	.0008	.0014	*.0004*	*.0001*	0.0005	-------
1917 to 1927	.0001	*.0002*	.0019	.0010	-------	-------

The best value of the change of f. in each column, i. e. the one obtained from the means having the smallest standard error at both beginning and end of the interval, is indicated by italicizing. It will be observed that these changes are mostly smaller than the standard errors of the means on which they are based, whereas the differences should be three times as large as the standard errors to indicate progressive change, with certainty.

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DISCUSSION

It is a source of gratification that further comparisons between the Marvin and the Callendar pyrheliometer in use at Madison cast doubt upon a possible deterioration in the Callendar instrument, which earlier comparisons seemed to indicate. On account of the small number of these comparisons in the different periods compared, this point can not be considered definitely settled, however. It is therefore hoped that additional comparisons may be obtained from time to time.

I may add that similar comparisons that are obtained during nearly every month at Lincoln, Nebr., have not shown an appreciable change in the reduction factor for the Callendar pyrheliometer in use at that station, except on one occasion, when the bridge wire was injured and had to be replaced.

Mr. Miller's paper shows quite conclusively that the progressive diminution in the annual totals of radiation received at Madison is attributable to the increased smokiness of that part of the city in which the university and the Weather Bureau are located, due to the change from anthracite to bituminous coal for heating dwellings, and an increase in the number of dwellings in the university section of the city. The same thing is true at the American University, District of Columbia, where, also, the depletion is confined to the winter months.—*H. H. Kimball.*

THE FUTURE OF AGRICULTURAL METEOROLOGY

By W. A. MATTICE

[Weather Bureau, Washington, August, 1931]

In these days of overproduction of agricultural products, with a corresponding depression of prices, the thoughts of the Nation turn to the plight of the farmer. There are many experiment stations, experimental farms, and various governmental agencies that are continually advising the farmer what crops to grow and what crops not to grow, but has the weather received full consideration in these opinions? The ever-present alchemist that transmutes base materials into the gold of the ripe wheat, corn, etc., has been scarcely accorded the measure of respect due the vast power wielded. The weather in its effect on agriculture has been scrutinized from afar, as through a long-range telescope, but very little has been accomplished in pursuing the microscopic detail necessary for complete understanding of the underlying principles involved in crop growth. The experimenter in physics, for example, does not attack his problems with the pick and shovel of the day laborer, but with intricate machinery, delicate lenses, accurate micrometers, etc. The comparison is perfectly analogous, for the present-day researches in agricultural meteorology are conducted on a grand scale, a State unit, district unit, or even a country-wide unit. The wealth of detail obtainable on such scales are meager, it is indeed, comparable to the pick and shovel of the day laborer. We might as well supply the archeologist with dynamite alone and expect him to return with the delicate murals, friezes, urns, etc., that are obtained only through infinite patience and careful brushing and screening of minute fragments.

Statistical studies of crop production as related to weather conditions have been and are still being made, with variable results. It is the present experience of investigators that, a series of correlations reaching a coefficient of 0.90, or a little better, is about as good as can be expected with available crop and weather data. However, a coefficient of 0.90 leaves much to be desired, for even with one this high there still remains 43 per cent of the spread between the actual and computed figures to be accounted for outside the data included in the equations. How can this gap be bridged; and is the inadequacy of the data the stumbling block?

The Weather Bureau includes in its meteorological statistics for first-order stations, in addition to temperature and rainfall, the hours of sunshine, direction of the wind, state of the weather, barometric pressure, vapor pressure, relative humidity, etc. Perhaps these, or at least some of them, have important relations to crops, but what material benefit are they when measured on the top of an office building sometimes four or five, or even more, miles from the nearest crops? Again, these first-order stations are widely separated—they are seldom nearer than 50 miles from each other and the various States rarely have over six or seven of them. What variations in the weather occur between them?

The cooperative stations are nearer the crops, being mostly in small towns, or even on farms, in some instances, but they measure only rainfall and temperature once a day and have no self-recording instruments that keep a continuous record. Thus, for these which are more directly applicable, many weather phases are not available.

The crop statistics are even more hazy and generalized, in addition to being relatively inaccessible. We can find easily the estimated yield per acre or total acreage, for the most available data give these figures on a State unit basis, but yields often vary widely in different parts of a State. Local, even in most places county, temperature and rainfall data are available, but what about corresponding yield figures? They are to be had in some individual State publications, but a complete file for one State is difficult to find outside the issuing office and then the series is rarely carried back far enough to be of material value for study purposes. Even if county figures were more readily available, we are again handicapped by the lack of detail, only yield per acre and total acreage being given.

If we are studying corn, for example, when was the crop planted, when did it first appear above ground, when were first leaves seen, when was it knee-high and waist-high, when did ears first appear, silking, tasseling, when in milk, dough, and early roasting-ear stages, when mature? Are there any answers to these important questions? Maybe, locally, at certain experiment stations or elsewhere, but are these records continuous for the same crop under the same cultural practices for 25 years, or more?

The problem at present is to account for the 40 per cent divergence between the predicted and actual yields. Assuming we have carried our study to the 0.90 coefficient mark, and that phenological data in sufficient detail are available for 25 years, what about weather data in corresponding detail? These should be available for at least the neighborhood of the growing crops. At most State experiment stations, unless unusually well equipped, there are maximum and minimum thermometers and a rain gage. These are read at about 4 p. m. or 8 a. m. and the maximum and minimum temperature, set maximum temperature, and total rainfall entered on forms. Where are the details? How much sunshine, what was soil temperature, when did rain occur, how long were temperatures above or below a significant value, what was the relative humidity, rate of evaporation, etc.?

Even if the above questions were satisfactorily answered how can we be sure that we have everything we need? Maybe we need leaf temperature, intensity of solar radiation, plant transpiration, moisture of the soil at different depths, and many other details too numerous to mention.

CONCLUSION

Are we doing everything possible to facilitate the study of crop production in its relation to the weather on a large scale, or even in local areas? There have been some beginnings. Some phenological studies have been made here and there, notably those of Thomas Mikesell, but only in very localized sections. The State weather and crop service of Iowa is at present engaged in collection of phenological data, but the records are still short. There are, at present, no known systematic researches being conducted of the direct relation of weather to crops under field conditions, where detailed weather and crop data are collected, side by side.

We breed high yielding corn, wheat, and oats, drought-resistant corn, rust-resistant wheat, etc., but too little is known of the effect of weather on crops in their various stages of development. We know hot, dry weather hurts wheat at heading time and corn when tasseling and some other generalizations, but that largely comprises the extent of our knowledge at present.

To enable us to know just how the weather is affecting a crop at any time, to forecast crops accurately, and to practice agricultural meteorology as a science and not as an art, we need accurate and comparable data of weather and of crop progress, with the details of various weather phases and of crop development from planting to harvest accurately observed and recorded on the ground.

TOR BERGERON'S ÜBER DIE DREIDIMENSIONAL VERKNÜPFENDE WETTERANALYSE [1]

By ERIK BJORKDAL

[Translated from German text by Andrew Thomson]

Translator's note.—This large and important work of 110 pages (31 by 23 centimeters) with 6 plates and 25 figures written by Doctor Bergeron of the Norwegian Meteorological Office at Oslo constitutes the most important recent summary of the technique of the Norwegian School of Meteorology.

Due largely to the absence of definite guidance on how to locate "fronts" on the weather map, considerable misunderstanding of polar front methods has arisen. Prof. J. Bjerkness's memoir [2] on Practical Examples of Polar Front Analysis, written in 1926, deals with specific cases of fronts passing over the British Isles, whereas Doctor Bergeron discusses the general principles of frontology equally applicable to Europe and to North America.

The following illuminating review by Doctor Bergeron's colleague indicates the field covered by Doctor Bergeron's extremely valuable and suggestive book which is marred for English readers by an involved style of sentence structure:

This work gives the first systematic exposition of the analytical methods of the so-called Bergen School of Meteorology. It discusses the existence and formation of tropospherical air masses and air separations, as well as their decisive importance for weather. Until further empirical investigations have been carried out the results hold only during the winter season over North America, north Atlantic, and western Europe.

The author first attacks the view which has often been advocated that the chief seat of pressure variations and weather changes may be sought in the substratosphere. He brings forward various plausible reasons for believing that the extratropical transformations of energy have their seat essentially in the troposphere and even in its lower half. There the weather actually displays itself.

The study of the structure of the troposphere is thus of fundamental importance. Already before the work of the Bergen meteorologists, various investigators had deserted pure isobaric geometry and realized there was a battle between air masses. But none of them was lead from their theoretical considerations to the daily weather map and no one realized that the boundary surfaces were entities of which the properties and dynamics

[1] Bergeron, T.: Ueber die Dreidemensional Verknüpfende Wetteranalyse, I. Teil. Geophys. Pub., Oslo, vol. 5, No. 6, 1928.
[2] Geophysical Memoir No. 50, British Meteorological Office, London, 1930.

could be studied. This was first done in the works of J. Bjerknes and H. Solberg.

The complete 3-dimensional weather analysis can be attained only by the utilization of the inner connections which exist between the fields of the meteorologist elements and between their singularities. Two-dimensional fields may be constructed from the ordinary continuously recorded data, but one must consider that the local and individual derivatives of the elements, without further information, can not be interchanged. The registrations show in addition that linear interpolation between adjacent air particles can be employed only within a homogenous air mass. With the passing of a front, linear interpolations can be employed no longer.

The analysis should be based only on representative observations. Representative temperature data should fulfill the condition that the mean vertical temperature gradient has approached already its characteristic value in the free air for the air mass under consideration. Frequently nonadiabatic influences disturb the temperatures at the earth's surface, so that they cease to be representative. Already in 1919 the Bergen school had adopted the view that temperatures of the free air and of mountain peaks should have special weight.

If the source and path of an air mass are known, then the internal changes during its transport can be estimated. Starting with the conditions in the area of origin one can judge the value of the characteristics of the air mass and of their height distribution along its path. In the first place, the approximately conservative properties must be considered; that is, those properties of which the intensity in any individual element of mass remain practically constant. Certain thermal and chemical properties belong to these classes.

Potential temperature and vertical temperature gradient are, with certain reservations, conservative. Admixtures of suspensions of particles so fine that they take part almost completely in the air movement presumably belong to the conservative chemical properties. These produce an opalescent turbidity of the air which has been investigated by the author at Swedish and Norwegian stations. Here the essential part of the pure opalescent turbidity arises out of desert or continental dust which has been transported northward from the subtropical high-pressure zone.

The breaking up of the troposphere into great currents appears markedly in winter through the striking great-scale features of the pressure field. In these currents the air masses concerned will be subjected to two fundamentally different types of exterior influences.

One mass which moves over the ocean toward an always increasing warmer understratum will increase its entropy. On the other hand, an air mass which goes over the ocean with ever colder surface temperatures loses entropy. Thus two chief types of air mass are probable, which are designated by the terms "cold-air mass" and "warm-air mass." Of these chief types, "polar air" and "tropical air" are the most important representatives.

The cold air mass will be formed mostly in polar areas and in winter generally in the continental anticyclones of higher latitudes. It is in its area of origin, cold, dry, and especially at lower levels stabile. It moves in general Equatorward so that the difference between air temperature and sea temperature is negative. The entropy supply exerts its greatest effects on the lowest layers of the air, which experience an increase of potential temperature and of vertical temperature gradient.

Experience has shown that after the cold air mass has traveled for about 200 kilometers over distinctly warmer ocean it has already taken up sufficient moisture that its humid air content is brought over the condensation level. Cu-Nb clouds with anvil form and even slight precipitation occur. On account of lively up and down movements definite clearings and pieces of clear sky may be observed. Because of the great turbulence any fog which happened to be present can only persist in small zones where it appears below a temporary calm. The system of hydrometeors can be characterized as belonging to shower air.

The warm air mass is usually generated in the oceanic highs of the Tropics and in summer over every great snow-free and ice-free land surface. It is in its area of origin warm—in the case of continental air also dry—and stratified approximately according to its radiation equilibrium. On the average it moves poleward so that the difference in temperature of the air and the land or ocean over which it travels is positive or zero. The entropy losses affect most strongly the lowest layers, which experience a reduction of vertical temperature gradient. The upward transport of humidity will be a minimum and the slight heat transport will be directed downward. The potential temperature will exhibit slight change.

Various cooling effects give rise to stratiform cloud and to fog, which on account of the small convection persists without dissipation. The warm air mass exhibits pervading bad visibility because of the tendency for fog formation. The system of hydrometeors can be characterized as belonging to drizzle air.

The direct empirical grounds for the properties of the air masses described can be supplied only through exhaustive synoptical research. This will be the work of the second part. Part I already deals statistically with the relation between the probable air masses and the difference between air and sea temperatures, vertical temperature gradient, and hydrometeors.

The temperature difference is investigated from the data of Dutch lightships and the dependence on origin of air mass confirmed.

The aerological airplane ascents at Berck, near Boulogne, 1918–19, give good reasons for believing that shower air and drizzle air are of fundamentally different structure. For the same surface temperature, there was a temperature difference of 9° C. of the two masses at 3 kilometers height. In drizzle air the chief condensation layer was about 1 kilometer above the ground, above which the humidity fell rapidly. In shower air no sharply bounded chief layer of condensation existed, while above 3 kilometers the relative humidity was distinctly greater than in drizzle air.

Several observations in Berck support the author's theory that the coming together of thick and compact water clouds with layers of permanent ice crystals is, except for drizzle, a chief source for all usual precipitation.

Conclusions may be deduced from the kind of hydrometeor regarding the thermodynamics and dynamics of the classified air mass. In the author's opinion the following threefold grouping of hydrometeors recommends itself for adoption in international observation technique:

(1) Ordinary rain (snow)—Either ordinary raindrops (snowflakes) or scanty fine droplets.

(2) Drizzle—Exclusively very fine droplets with great number of drops per unit volume.

(3) Showers—Sharp intermittency of precipitation and medium cloud cover.

From a consideration of the mode of formation of cold air and warm air masses it could be expected that a positive difference between air and sea temperatures corresponds to drizzle and a negative difference to shower air. The author has investigated this rule from 620 observations taken at Thorshavn and found that the rule holds good without exception for differences greater than 0.5° C. For smaller differences no definite contradiction could be established. It thus follows that accurate measurements of air and sea temperatures at all international island and ship stations and their report to 1/10° C. or 1/5° F. have great importance for practical weather analysis.

The investigations of the author on horizontal visibility in Scandinavia confirmed the hypothesis that the opalescent turbidity of the warm air mass is notably greater than of the cold air mass.

From a previous work of the author (Wellen und Wirbel, Leipzig, 1924) it is known that surfaces of equal entropy (isentropic surfaces) of the cold mass are inclined upward toward the pole, while in the warm air mass they are almost horizontal. Thus is follows, as is later discussed in detail, that the cold mass easily becomes heterogeneous while the warm air mass with horizontal isentropic surfaces is among the most homogeneous masses of the atmosphere.

By means of aerological data from Holland and Spieglitzer, Schneeberg, the existence of at least two separate air masses is statistically indicated. The potential temperature has at any level two pronounced frequency maxima which correspond to polar air and tropical air.

When two air masses each uniformly homogeneous approach each other nearer than about 1,000 kilometers, the area between them no longer fulfills the conditions of a homogeneous air mass. A frontal zone occurs which can gradually sharpen to a front. Fronts are narrow inclined transition zones of the same vertical extent as the air masses. It is essential that the difference of the values on both sides of the front of at least one of the independent elements (temperature, pressure, wind, humidity) is so great that it has an appreciable effect on the great scale dynamics (of the air mass).

In the troposphere, fronts are continuously produced and destroyed. The author has called these processes frontogenesis and frontolysis. Kinematic frontogenesis consists in the coming together of the equiscalar surfaces of an element through the motion of the individual particles.

In dealing with air masses which are not too extended the field of movement can be treated as linear. The movement itself may be resolved into four partial fields consisting of a translation, a rotation, an expansion, and a deformation. Only through the deformation movement can two particles essentially approach or separate from one another.

As no essential change of volume can occur, a deformation is undergone either as an extension along the principal axis and a contraction along both secondary axis or as a contraction along the principal axis and an extension along the secondary axis. Material particles which at one time form a plane surface will always form a plane surface which during movement alter only their orientation and their distance from the field's center. In a 2-dimensional field the surfaces rotate so that they will ultimately be perpendicular to the axis of greatest contraction.

A symmetrical deformation field with vertical axis produces the following effects—the extension of the principal axis causes dissolution of horizontal inversion zones while contraction brings sharpening.

A 2-dimensional half deformation field with one horizontal axis and an axis directed obliquely upward causes frontogenesis and dissolution of inversions. Contraction along the horizontal axis causes frontolysis, while expansion causes inversion formation.

The choice of entropy surfaces as equiscalar surfaces presupposes advective frontogenesis. Thus from the beginning the entropy surfaces are inclined and advection comprises a permanent deformation-field of which the axis of contraction can not be directly vertical. It thus follows, as has been previously pointed out, that in the warm air mass where the isentropic surfaces are almost horizontal almost no frontogenesis occurs; in the cold mass where they are somewhat inclined, weak frontogenesis; and in frontal zones where they are considerably inclined there is effective frontogenesis.

The general circulation of the earth's atmosphere is divided into several partial circulations. They can be considered as a system of vertical wheels and of horizontal wheels. The hyperbolic points between the wheels are the centers of the deformation fields in the foregoing sense. Frontogenesis and frontolysis develop in the areas between the parts of the general circulation. The effect of the vertical wheels and horizontal wheels will alternately strengthen and oppose each other.

When the general circulation works frontogenetically, areas occur where by preference fronts are formed. The favored frontal zones run east and west. In the intermediate zone where the vertical opposes the horizontal circulation, the resulting effect will be mostly frontolysis so that the air exchange between pole and Equator can go on unhindered.

Doctor Bergeron's book is conceived as the principle introduction to the problem of air masses and front formation. The use of the results for investigating the relations actually occurring in the troposphere will be shown in Part II. The wish may be expressed that we may not need to wait long for this continuation.

ON PERIODICITY IN SERIES OF RELATED TERMS [1]

By Sir Gilbert Walker, F. R. S.

SUMMARY

In 1927 Yule developed the idea that a series of numbers $u_1, u_2, \ldots, u_n$ expressing the condition of a physical system, such as successive annual sun-spot numbers, might be regarded as due to a series of accidental disturbances from outside operating on some dynamical system with a period or periods of its own, probably subject to damping. The consequent oscillations would vary both in amplitude and in period. In this paper it is shown that if Yule's equation defining the relationship between successive undisturbed terms of the u series is

$$u_u = g_1 u_{x-1} + g_2 u_{x-2} + \ldots + g_s u_{x-s},$$

then, provided n is large, a similar equation holds very approximately between successive values of r_p, the correlation coefficient between terms of u separated by p intervals, i. e.,

$$r_x = g_1 r_{x-1} + g_2 r_{x-2} + \ldots + g_s r_{x-s}.$$

[1] On periodicities in series of related terms, Proc. Roy. Soc. Series A, vol. 131, No. 818, pp. 518-532.

* The subject is treated from the mathematical viewpoint and since no one's views are entitled to greater consideration than those of Sir Gilbert we print in his own words the summary of his conclusions.—Ed.

Thus the graph expressing the r_p's, which is much smoother than that of the u's, may be used to read off the character of the natural periods of the u's; further various relationships are found between the amplitude of the corresponding terms in the Fourier periods and those of the correlation coefficients.

The analysis is illustrated by applying it to the quarterly values of pressure at Port Darwin, a key center of world weather, which proves to have a strong persistence and to show evidence of not very strongly developed periods of about 34½ months and of about four times this length or 11½ years; the series of data is not long enough to settle whether the former oscillations are damped and are free oscillations, but the latter appear to be imposed from without and are presumably solar in origin.

WULF AND MELVIN ON THE EFFECT OF TEMPERATURE UPON THE ULTRA-VIOLET BAND SPECTRUM OF OZONE AND THE STRUCTURE OF THIS SPECTRUM

The ultra-violet absorption of ozone in the region 3400–2300 Å consists of a large number of bands appearing against a background of continuous absorption. The effect of temperature upon this spectrum has been studied over the range −78° to 250° C. A definite though small effect has been observed. Grossly it manifests itself as an increase in contrast with decreasing temperature. Photometric results show this to be chiefly a decrease in absorption between the band edges, all of the bands appearing to come from normal vibrational levels of very low if not the lowest energy. Though somewhat diffuse, the bands tend to degrade to the red. The observed influence of temperature can be explained as the decrease of intensity in the higher rotational absorption of the bands, and possibly also in the continuous background, with decreasing temperature. Discontinuities in the intensity relations and the regular spacing of certain of the bands have led to a partial vibrational analysis indicating two active vibrational degrees of freedom in the excited electronic state. The observed change in the absorption with temperature may effect somewhat the estimates which have been made of the amount of ozone existing in the upper atmosphere.—(*Bulletin of the American Physical Society, Program of the Washington Meeting, April 16, 1931, volume 6, No. 2, page 42.*)

FATHER E. GHERZI, S. J., ON THE WINDS AND UPPER AIR CURRENTS ALONG THE CHINA COAST AND IN THE YANGTSE VALLEY [1]

The publication under review comes from the well known observatory of Zi-Ka-Wei, near Shanghai, organized more than half a century ago and operated in the interest of meteorology with special application to storm warnings for navigators of the adjacent seas. The present publication has its special appeal to navigators of the air in the Far East.

The upper air data available to Father Gherzi are far too few to afford definite reuslts; nevertheless those at hand in connection with the movement of the clouds and the surface winds, statistics of which are abundant, enable the author to present a picture of free air conditions that is of much value in air navigation.

His pilot-balloon material consists of ascents made at Chefoo by the U. S. S. *Jason* in May, June, July, August, and September, 1928; pilot-balloon ascents were also contributed by H. M. S. *Argus* at Shanghai made in October, November, and December, a few ascents in each month. These ascents though few in number serve to indicate the direction and force of the winter monsoon winds along the China coast. As might be expected these winds are due essentially to the presence and the intensity of the so-called Siberian cold season anticyclone; the center of which may be over the Province of Shantung in China, rather than in Siberia. Father Gherzi concludes that for winter monsoon days the winds aloft back with increase in altitude above the surface. Data for the summer monsoon are much too few to permit the drawing of definite conclusions. Conditions during the summer monsoon are much less ready than during the winter monsoon.

The statistical data of surface winds are given in very great deatil for a number of stations on the China coast. The 240 quarto pages comprised in the report are mostly taken up with data of cloud movement and surface air movement printed in detail for a number of years of record. Appropriate charts and diagrams add to the interpretation of the statistics. The price of the work is $4.50.—*A. J. Henry.*

[1] The winds and upper air currents along the China coast and in the Yangtse Valley Zi-Ka-Wei Observatory, Shanghai, 1931.

RESULTS OF RAINFALL OBSERVATIONS IN WESTERN AUSTRALIA [1]

The present volume is the fifth of a series published by the bureau. Volumes for Victoria (1910), N. S. Wales (1914), Queen Island and South Pacific (1913), South and North Australia (1917) have already been published. The last volume, discussing Tasmania, is under preparation. As soon as the series is completed supplementary volumes are to be published to bring the early issues up to date.

The present volume contains a concise history of the rainfall and weather of western Australia, from the time records began up to the end of 1927. A few of the records go back as far as 1877 and even earlier. The number of stations is 1,374.

The work contains a written tabular history of rainfall by months from 1877 to 1926; a short note on the climate of western Australia; a discussion of the relationships between wheat yield and rainfall; a record of notable meteorological events in the State, e. g., auroræ australis, bush fires, earthquakes, floods, etc. These occupy half of the volume. The second part of the volume contains the annual rainfall data of all stations in western Australia. At the end of the volume annual rainfall maps for western Australia from 1886 to 1927 are published, and also a revised annual rainfall map of Australia.

This publication is valuable to all those interested in the climate of western Australia, but especially to agriculturists and sailors. It lacks a thorough discussion of the rainfall and weather but it is an excellent source book containing the available data and written history of the weather in western Australia. Especially valuable are the numerous maps and charts included in the 387 pages of text.—*Sigismond R. Diettrich.*

PROF. ALEXANDER McADIE RETIRES FROM BLUE HILL OBSERVATORY

After sabbatical leave for the first semester of the coming academic year, Alexander McAdie, Abbot Lawrence Rotch professor of meteorology, Harvard University, and director of Blue Hill Observatory, will become professor emeritus.

[1] Results of rainfall observations made in western Australia, Commonwealth of Australia, Bureau of Meteorology, under the direction of H. A. Hunt, Commonwealth meteorologist, 1929, p. 387.

In recognition of his long and distinguished service and his notable contributions to man's knowledge and understanding of the weather, a dinner was given Professor McAdie on June 11 by the Harvard visiting committee to Blue Hill Observatory, and a silver bowl was presented to him and Mrs. McAdie as a token of the committee's affection. Professor and Mrs. McAdie will make their home at Hampton, Va.—(*Bulletin American Meteorological Society August-September, 1931, p. 158.*)

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING JULY, 1931

By Herbert H. Kimball, Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, Review, page 41.

Table 1 shows that solar radiation intensities averaged above the normal intensities for July at Madison, and close to the July normals at Washington and Lincoln.

Table 2 shows an excess in the total radiation received on a horizontal surface as compared with the normal amounts for July at Madison and Fresno, and a deficiency at all other stations for which normals have been computed.

Skylight polarization measurements obtained on 8 days at Madison, give a mean of 60 per cent with a maximum of 70 per cent on the 24th. At Washington, measurements obtained on 4 days give a mean of 53 per cent, with a maximum of 58 per cent on the 27th. These are close to the corresponding July averages for both stations.

Table 1.—*Solar radiation intensities during July, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
July 8	17.37	------	------	------	0.72	------	------	------	------	------	18.59
July 11	14.10	------	------	0.78	0.99	1.26	------	------	------	------	10.97
July 14	19.23	------	------	------	0.82	1.14	------	------	------	------	20.57
July 15	17.96	------	------	------	0.74	------	------	------	------	------	17.96
July 22	13.61	------	------	------	1.09	1.32	------	------	------	------	13.13
July 23	13.61	------	------	0.78	0.99	1.17	------	------	------	------	13.61
July 25	13.13	------	------	0.76	0.98	1.25	------	------	------	------	8.81
July 27	16.79	------	0.63	0.80	1.00	1.18	------	------	------	------	10.97
July 28	18.59	------	------	------	0.82	1.14	------	------	------	------	14.60
July 29	19.89	------	------	0.84	0.88	------	------	------	------	------	14.60
Means	------	------	(0.63)	0.79	0.90	1.21	------	------	------	------	------
Departures	------	------	−0.04	+0.02	±0.00	+0.02	------	------	------	------	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during July, 1931*—Contd.

Madison, Wis.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass A. M.					Air mass P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
July 1	17.96	------	0.54	0.69	0.85	1.12	------	------	------	------	16.79
July 6	12.24	------	1.01	1.12	1.25	1.39	1.14	0.95	------	------	10.51
July 7	9.47	------	------	------	------	1.44	1.17	0.94	------	------	6.76
July 8	10.21	0.85	0.91	0.99	1.16	1.40	------	------	------	------	7.57
July 9	8.81	0.81	0.94	1.02	------	------	------	------	------	------	9.83
July 10	6.27	------	------	------	------	1.36	------	------	------	------	7.29
July 11	8.81	------	------	------	0.96	------	------	------	------	------	7.87
July 14	16.20	------	------	0.74	0.91	------	------	------	------	------	16.79
July 15	15.65	------	------	------	------	1.14	0.91	0.71	------	------	17.37
July 16	15.65	------	0.73	0.87	1.04	------	------	------	------	------	16.20
July 18	10.59	------	------	------	------	1.45	------	------	------	------	9.14
July 21	10.59	------	------	------	------	1.23	------	------	------	------	10.59
July 22	10.97	------	------	------	------	1.39	1.19	1.03	------	------	9.83
July 24	10.59	------	0.92	1.06	1.23	1.42	1.10	0.95	0.77	------	6.76
July 25	10.97	------	------	0.92	1.04	------	------	------	------	------	9.83
Means	------	(0.83)	0.84	0.93	1.06	1.33	1.10	0.92	(0.77)	------	------
Departures	------	+0.12	+0.04	+0.02	±0.00	+0.05	+0.08	+0.01	------	------	------

Lincoln, Nebr.

Date	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
July 13	14.60	------	------	------	------	1.28	1.02	0.81	0.67	------	17.37
July 14	14.60	------	0.65	0.78	0.98	1.23	0.94	0.75	------	------	17.37
July 16	17.37	------	------	0.93	1.14	1.36	------	------	------	------	17.37
July 20	13.13	------	------	------	------	------	1.16	0.97	0.80	------	11.38
July 21	12.24	------	------	0.93	1.13	1.35	------	------	------	------	11.38
July 23	11.38	------	------	------	------	1.36	1.15	0.99	0.84	------	9.47
July 24	10.97	------	0.84	0.96	1.10	------	------	------	------	------	9.14
July 25	12.68	------	0.77	0.85	1.04	1.21	1.07	0.88	0.73	------	12.24
July 27	19.23	------	0.72	0.85	1.06	1.30	1.00	0.81	0.64	------	17.96
Means	------	------	0.74	0.88	1.08	1.30	1.06	0.87	0.74	------	------
Departures	------	------	−0.04	−0.01	±0.00	−0.02	±0.00	−0.01	+0.01	------	------

TABLE 2.—*Total solar radiation (direct diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
	AVERAGE DAILY TOTALS											
1931	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 2	418	533	507	424	316	709	453	464	726	360	604	403
July 9	475	542	549	406	403	655	442	[1] 287	754	387	589	272
July 16	444	587	527	406	336	624	393	------	708	345	564	349
July 23	583	574	607	464	415	455	550	440	619	423	593	279
	DEPARTURES FROM WEEKLY NORMALS											
July 2	−84	+1	−71	−14	−97	+48	−31	−14	+12	−96	----	----
July 9	−11	+10	−23	−19	+1	−37	−39	−205	+46	−73	----	----
July 16	−300	+72	−41	−10	−60	−56	−83	------	+8	−123	----	----
July 23	+97	+74	+62	+65	+17	−186	+48	−108	−59	−22	----	----
Accumulated departures on July 29, 1931	+1265	−3192	−77	−1169	−1190	−1063	−1863	−2823	−266	−4872	----	----

[1] 5-day mean.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, includin gspots and groups is given for each day in the last column]

Date	Eastern standard civil time		Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1931	h	m	°	°	°			
July 1 (Naval Observatory)	10	50	−52.0	74.4	+6.0	------	154	------
			−42.0	84.4	−10.0	62	------	216
July 2 (Naval Observatory)	11	57	−35.0	77.6	+5.0	------	77	77
July 3 (Naval Observatory)	10	56	−22.0	77.9	+5.0	------	77	77
July 4 (Mount Wilson)	12	45	−13.0	72.6	+5.0	------	16	------
			0.0	85.6	−8.0	------	64	

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1931	h	m	°	°	°			
July 5 (Naval Observatory)	10	48	−3.0	70.5	+5.0	------	31	------
			+11.0	84.5	+6.0	------	31	62
July 6 (Naval Observatory)	13	22	−31.0	27.8	+8.0	3	------	------
			+4.0	62.8	+9.0	------	31	------
			+27.0	85.8	+5.0	------	62	96
July 7 (Naval Observatory)	11	2	−62.0	344.9	−21.0	------	62	------
			−39.5	7.4	−9.0	------	93	------
			+5.0	51.9	+11.5	------	31	186
July 8 (Naval Observatory)	11	13	−78.0	315.6	−13.0	------	62	------
			−50.0	343.6	−22.0	31	------	------
			−25.0	8.6	−9.0	------	108	------
			+12.0	45.6	−3.0	15	------	216
July 9 (Perkins Observatory)	13	30	−83.0	296.0	−5.0	100	------	------
			−79.0	300.0	+1.0	93	------	------
			−29.0	350.0	−11.0	93	------	286
July 10 (Naval Observatory)	16	32	−50.0	314.2	−11.5	------	77	------
			−21.0	343.2	−21.0	15	------	------
			−8.0	356.2	−19.0	15	------	------
			+7.5	11.7	−8.0	------	77	184
July 11 (Naval Observatory)	10	43	−38.0	316.1	−12.0	------	31	------
			+3.0	357.1	−20.0	6	------	------
			+19.5	13.6	−8.0	15	------	52
July 12 (Mount Wilson)	11	50	−24.0	316.3	−12.0	18	------	------
			−8.0	332.3	+5.0	3	------	------
			+15.0	355.3	−19.0	------	44	------
			+33.0	13.3	−8.0	------	36	101
July 13 (Naval Observatory)	10	58	−10.5	317.0	−12.0	9	------	------
			−0.1	327.4	+0.5	3	------	------
			+4.0	331.5	+15.0	3	------	------
			+25.0	352.5	+17.0	3	------	------
			+30.0	357.5	−20.0	6	------	------
			+49.0	16.5	−7.5	6	------	30
July 14 (Naval Observatory)	11	35	−55.0	258.9	+12.0	3	------	------
			−46.0	267.9	+17.0	3	------	------
			+4.5	318.4	−12.0	9	------	------
			+7.5	321.4	+13.0	3	------	------
			+16.0	329.9	−16.0	3	------	------
			+43.0	356.9	−19.5	3	------	------
			+65.0	18.9	−8.0	6	------	30
July 15 (Naval Observatory)	10	53	−13.0	288.1	−16.0	3	------	------
			+12.0	313.1	−15.0	3	------	------
			+16.0	317.1	+9.5	3	------	------
			+18.0	319.1	−13.0	9	------	18
July 16 (Naval Observatory)	10	58	+29.0	316.8	−8.0	6	------	6
July 17 (Naval Observatory)	10	41	+7.5	282.3	+8.0	------	9	9
July 18 (Naval Observatory)	10	32	No spots					
July 19 (Naval Observatory)	10	55	No spots			------	------	------
July 20 (Naval Observatory)	10	54	No spots			------	------	------
July 21 (Naval Observatory)	10	41	−62.0	159.8	+7.5	------	31	31
July 22 (Naval Observatory)	11	6	−49.5	158.9	+8.0	------	45	45
July 23 (Naval Observatory)	10	56	−33.0	162.2	+8.0	------	15	------
			−14.0	181.2	−4.0	6	------	------
			−9.5	185.7	+2.5	6	------	------
			−0.5	194.7	+23.0	------	22	49
July 24 (Naval Observatory)	13	48	−19.5	160.9	+6.5	------	15	15
July 25 (Naval Observatory)	10	40	No spots			------	------	------
July 26 (Naval Observatory)	10	50	−80.0	75.6	+7.0	------	31	31
July 27 (Naval Observatory)	10	49	−62.0	80.4	+7.0	31	------	31
July 28 (Naval Observatory)	10	45	−52.0	77.2	+5.0	------	62	------
			+40.0	169.2	−1.5	15	------	77
July 29 (Naval Observatory)	10	50	−43.0	72.9	+12.0	9	------	------
			−38.0	77.9	+7.0	37	------	------
			+59.0	174.9	−7.0	6	------	52
July 30 (Naval Observatory)	10	36	−25.0	77.8	+8.0	------	108	------
			−18.0	84.8	−6.0	------	62	170
July 31 (Naval Observatory)	10	50	−11.0	78.5	+7.0	------	93	------
			−3.5	86.0	−6.0	------	77	170
Mean daily area for July	------		------	------	------	------	------	77

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JULY, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich Switzerland]

July, 1931	Relative numbers	July, 1931	Relative numbers	July, 1931	Relative numbers
1	22	11	35	21	Ec 7
2	23	12	26	22	10
3	23	13	30	23	8
4	19	14	23	24	8
5	a 19	15	8	25	8
6	16	16	7	26	0
7	Ec —	17	8	27	Ec 7
8	35	18	7	28	9
9	28	19	0	29	Ec 22
10	Mac 48	20	0	30	23
				31	23

Mean: 30 days = 16.7.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group or spot through the central meridian.
c = New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in Charge]

By L. T. SAMUELS

During July the Weather Bureau began daily airplane observation flights at Chicago, Cleveland, and Dallas and continued kite observations at Due West and Ellendale. The mean monthly free-air temperatures and relative humidities for these stations and those of the Navy are shown in Table 1. A comparison of these data with the normals based on nearby kite stations shows that the free-air temperatures were mostly above normal at all stations. Relative humidities were close to normal at all stations and vapor pressures were in general agreement with temperatures, i. e., above normal.

The resultant winds for the month were variable and light at the ground level. (Table 2.) At the 1,000-meter level the highest resultant velocities were found over the southern Plains States where they reached 8 meters per second with a strong southerly component. An easterly component persisted to 5,000 meters over Brownsville, Dallas, Key West, and Phoenix.

The superiority of airplanes over kites with respect to heights reached and regularity of flights is well brought out in Table 3 which shows the average and maximum heights reached and number of flights made.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during July, 1931*

TEMPERATURE (°C)

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (3 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)	Washington, D. C.[3] (2 meters)
Surface	20.0	19.3	24.8	27.2	21.4	26.9	26.3	24.0	25.0
500	21.8	20.7	25.9	24.5	20.9	24.2	24.6	19.9	24.5
1,000	21.4	20.8	24.7	22.1	19.2	21.8	22.0	23.0	22.8
1,500	18.3	18.1	22.1	18.9	17.0	------	------	------	------
2,000	15.1	15.1	19.2	15.5	14.3	15.3	16.0	21.0	16.7
2,500	11.9	12.3	16.0	11.9	11.3	------	------	------	------
3,000	8.8	9.8	12.8	8.8	8.7	10.1	9.7	13.0	10.6
4,000	2.6	4.4	5.9	2.8	2.3	------	3.2	------	4.8
5,000	−3.8	−1.1	−0.3	------	−5.5	------	−1.4	------	−1.4
6,000	------	−6.6	------	------	------	------	------	------	------

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Chicago, Ill.	Cleveland, Ohio	Dallas, Tex.	Due West, S. C.	Ellendale, N. Dak.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	82	85	76	75	62	77	89	70	75
500	64	73	70	75	62	71	83	82	66
1,000	56	60	65	71	59	65	74	55	59
1,500	60	63	65	71	57	------	------	------	------
2,000	59	66	62	70	54	63	67	43	65
2,500	53	62	58	70	53	------	------	------	------
3,000	51	55	56	70	49	49	65	50	58
4,000	44	46	58	50	49	------	54	------	54
5,000	36	46	53	------	63	------	49	------	40
6,000	------	45	------	------	------	------	------	------	------

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a. m. (E. S. T.) during July, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 68 E	0.6	S 45 E	0.8	S 1 W	2.8	N 68 W	2.4	N 76 W	0.3	S 17 W	1.7	S 5 E	1.0	S 45 E	0.2	N 47 W	0.7	S 88 W	0.6	S 73 W	0.7	S 65 E	2.3
500	------	---	S 22 E	7.3	S 36 W	4.1	------	---	S 74 W	3.6	S 78 W	3.4	S 32 W	7.6	N 62 W	2.1	N 81 W	0.7	------	---	S 74 W	4.9	S 61 E	5.8
1,000	------	---	S 23 E	7.9	S 89 W	4.1	------	---	S 78 W	4.4	N 71 W	5.3	S 38 W	7.0	N 82 W	3.1	S 39 W	1.9	N 86 W	2.3	S 71 W	4.1	S 57 E	6.0
1,500	------	---	S 29 E	6.6	N 60 W	5.4	------	---	N 86 W	5.4	N 68 W	6.3	S 32 W	5.0	N 87 W	3.0	S 65 W	3.3	N 69 W	4.6	S 76 W	2.8	S 60 E	5.6
2,000	S 18 E	2.7	S 40 E	5.8	N 69 W	6.8	N 78 W	3.9	N 84 W	5.8	N 76 W	7.1	S 12 W	3.3	S 80 W	2.8	N 87 W	5.4	N 72 W	5.0	S 80 W	1.9	S 65 E	4.7
2,500	S 11 W	2.6	S 49 E	5.4	N 65 W	7.5	W	3.4	N 78 W	6.3	N 82 W	7.0	S 9 E	2.0	S 77 W	2.6	N 78 W	7.5	N 83 W	6.3	S 87 W	1.3	S 68 E	4.7
3,000	S 57 W	1.4	S 57 E	4.4	N 72 W	8.1	N 84 W	3.5	N 71 W	5.9	N 80 W	6.4	S 46 E	1.2	N 89 W	3.0	N 74 W	9.5	N 88 W	8.0	S 84 W	1.8	S 72 E	3.9
4,000	N 9 W	2.0	S 84 E	2.7	N 87 W	6.6	N 76 W	4.0	N 56 W	6.9	N 58 W	6.7	S 83 E	1.6	S 83 W	2.8	N 77 W	9.6	N 84 W	11.4	S 52 W	2.1	S 48 E	1.8
5,000	N 36 E	4.0	N 89 E	1.1	------	---	N 61 W	7.7	------	---	N 58 W	7.8	N 62 E	1.0	S 85 W	3.1	N 68 W	12.2	S 85 W	16.1	S 70 W	1.4	N 45 E	2.8

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 31 E	0.3	S 48 W	0.4	S 12 E	0.8	S 73 W	0.2	N 37 W	1.1	S 5 E	1.7	S 34 E	1.2	S 76 E	1.0	S 22 E	3.6	S 55 E	0.4	S 63 E	0.6	N 57 W	0.4
500	S 85 E	1.6	W	0.9	S 28 W	3.3	S 42 W	3.1	S 84 W	2.7	S 11 W	4.5	S 8 W	4.1	S 74 E	1.0	------	---	S 77 W	2.5	N 20 E	2.5	N 66 W	5.0
1,000	N 12 E	0.7	N 62 W	1.2	S 46 W	2.6	S 27 W	3.1	N 65 W	3.7	S 39 W	7.8	S 44 W	6.7	S 83 E	0.2	------	---	N 86 W	6.1	N 15 E	2.6	N 48 W	6.1
1,500	N 46 W	2.0	N 72 E	0.8	S 55 W	2.0	S 1 W	2.9	S 86 W	2.3	S 49 W	6.4	S 60 W	5.6	N 73 W	0.8	S 25 E	3.3	N 83 W	6.7	N 3 W	1.8	N 57 W	5.9
2,000	N 55 W	1.4	S 82 E	1.3	S 33 W	2.0	S 12 E	2.1	S 46 W	2.3	S 54 W	3.6	S 83 W	4.5	N 18 W	1.5	S 13 E	2.3	N 78 W	7.5	N 35 W	1.0	N 61 W	6.5
2,500	S 51 E	0.9	S 34 W	3.5	S 24 E	3.1	S 6 W	1.9	S 30 W	2.2	S 52 W	2.5	N 87 W	4.2	N 5 W	1.6	S 49 W	9.3	N 77 W	8.0	N 63 W	2.0	N 70 W	7.0
3,000	S 71 E	2.1	S 34 W	5.6	S 24 W	3.5	S 9 E	2.0	S 16 W	2.1	S 76 W	1.1	N 85 W	3.4	N 14 E	1.4	N 81 W	2.1	N 73 W	9.7	N 69 W	3.3	N 76 W	7.0
4,000	------	---	S 55 W	7.4	------	---	S 77 W	0.6	------	---	N 32 W	1.6	N 62 W	2.6	N 57 E	3.3	N 84 W	5.7	N 56 W	11.9	------	---	N 72 W	7.9
5,000	------	---	------	---	------	---	N 29 E	1.1	------	---	N 12 W	0.9	N 34 W	4.5	N 71 E	7.1	N 86 W	8.0	N 58 W	12.4	------	---	------	---

TABLE 3.—*Observations by means of airplanes, kites, captive and limited heights sounding balloons during July, 1931*

	Dallas, Tex.[1]	Due West, S. C.	Ellendale, N. Dak.	Chicago, Ill.[1]	Cleveland, Ohio[1]
Mean altitudes (meters), m. s. l., reached during month	5,460	3,186	3,561	4,917	5,841
Maximum altitude (meters), m. s. l., reached	5,977	[2] 4,794	5,626	5,539	6,355
Number of flights made	31	26	31	31	31
Number of days on which flights were made	31	26	29	31	31

[1] Airplanes. [2] Limited-height sounding balloon observation.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

[Climatological Division, Oliver L. Fassig in Charge]

By H. C. HUNTER

GENERAL SUMMARY

In practically all sections July was hotter than normal. The heat was comparatively steady in the majority of States, though several north-central stations set new high-temperature marks during the closing week. As a whole, the month was the hottest July ever recorded in most of the far Southwest and in portions of the Atlantic States; but the central area, while showing a large excess, failed to equal its earlier record.

The rainfall was irregular as to distribution, even within comparatively small areas. Usually there was more than normal from the Carolinas northward and northeastward, and along the Canadian boundary from Minnesota to Montana. Near the central and west Gulf coast there were some districts where marked shortages occurred, but amounts above normal were the rule, and several areas received quantities twice or thrice as great as normal. Deficient precipitation was the prevailing condition in the heart of the country and west of the Rocky Mountains. Most reports indicate numerous thunderstorms, abundant sunshine, and low relative humidity.

TEMPERATURE

The opening week of July was mainly hotter than normal, especially in the Lake region and the southeastern portion of the country, but about the 3d cool weather set in over the Missouri Valley, continuing until the 9th. After several days with temperature conditions showing no notable departures, high temperatures set in about the 14th to 16th over the Missouri and upper Mississippi Valleys and the Lake region, continuing without noteworthy break for the remainder of the month. The final decade was marked by considerable excess of temperature in the western and central thirds of the country and in the Northeast.

As a whole, July was at least as hot as normal in every State. In California and the Plateau region the month averaged about 5° to 7° hotter than normal, many stations in California and the western portions of Arizona and Nevada reporting it the hottest month of record. The departures of the mean temperature from the normal are shown on Chart I. As may be seen from that chart in the middle Rocky Mountain region and the middle and lower portions of the Missouri Valley, and thence eastward almost to the Atlantic coast, the month averaged usually 2° to 6° hotter than normal, and there was a like excess in the southern Appalachian region, where several stations noted that the mean temperature was higher than ever before in July.

In the lower Mississippi Valley the month was practically normal in its average temperature, and the same was true of Texas as a whole, but western and southwestern Texas averaged more than 1° cooler than normal.

Except in New England and Delaware, temperatures exceeding 100° were noted in every State. In Missouri, Minnesota, and Kansas, also all northern States from Nebraska and the Dakotas westward, and all Plateau and Pacific States there were readings of 110° or higher. The very highest temperature reported was 126° in southeastern California, while east of the Rocky Mountains 116° was noted at Redfield, S. Dak. The various States noted their highest temperatures usually during the first five days or between the 20th and the 29th.

The lowest temperature marks of the States were frequently in the 40's, but were higher in the Gulf and some of the least mountainous Atlantic States, while lower in the upper Lakes States, the northern Plains, the Rocky Mountain States, and the far West. The very lowest reported was 20° at three elevated stations in Colorado. The various low marks were noted chiefly between the 5th and the 12th.

PRECIPITATION

The inset on Chart V shows the departure of precipitation from normal.

The opening week of July brought much needed rains in many portions, especially Montana, North Dakota, the middle Plains, and from the central valleys eastward to the Carolina and Virginia coast. The succeeding week was mainly less rainy, but considerable parts of North Dakota, the upper Mississippi Valley, the southern Plains, and the Atlantic States had ample rainfall. Nearly all the Gulf coast districts received liberal amounts during the third week, as did the western half of the cotton region and the majority of States from Tennessee and North Carolina northward and northeastward. The final decade was marked by absence of substantial rains in most of the lower Missouri and upper Mississippi Valleys, and near Lakes Michigan and Superior; but, on the other hand, large parts of Arkansas, Mississippi, and Georgia, and of the upper Ohio Valley and northern New York and New England had abundant rains, and the last few days saw much rainfall over the Rocky Mountain and eastern Plateau regions, several portions of the Plains, and the west Gulf coast region.

The precipitation of July, as a whole, was comparatively well distributed and rather near to normal, for a summer month, this situation being more favorable than in almost any preceding summer month for several years. This was particularly true of the States which are situated east of the Plains, and wholly or largely south of the fortieth parallel of latitude, every one of these averaging at least 3 inches of rainfall and all save two having fully two-thirds of an inch at the stations reporting the least amounts. Mississippi received, on the average, almost 9 inches, and that State, with western Alabama and eastern Arkansas, had much greater rainfall than normal. Rainfall slightly above normal was the rule from the southern Appalachians and eastern South Carolina northward and northeastward, save that eastern New Jersey and southern New England fell short of normal. Usually there was more than normal from central Montana eastward over North Dakota to northwestern Minnesota, also from Montana southward to eastern Arizona, and in the central and southern portions of Texas.

There was usually considerably less rain than normal in the eastern portions of Florida and Georgia, the lower Ohio Valley, northern Ohio and adjacent parts of Michigan and Indiana, and southeastern Kansas and central Oklahoma. While there was considerable irregularity as to quantities received, there was mainly a decided shortage from northeastern Missouri northward to the vicinity of western Lake Superior and northwestward to beyond the Black Hills. The southwestern Plains and the eastern and central parts of New Mexico had moderate shortages, likewise southwestern Arizona, and practically all of Nevada, central and western Idaho, and the Pacific Northwest.

In Montana, as a whole, this was the first month to show more precipitation than normal since October, 1930; in Alabama and Mississippi, since November; and

in Oklahoma, Texas, and Arkansas, since March of the present year.

The largest monthly amount reported by any one station in the United States proper was 25.10 inches at Seven Hills, in Mobile County, Ala.

SUNSHINE AND RELATIVE HUMIDITY

The sunshine was of more than usual quantity during July in nearly all sections, even in most areas where the precipitation was heavy. The amount of sunshine was particularly large in the far Northwest and the upper Mississippi Valley; elsewhere it was usually equal to or moderately more than normal, but some portions of the central and eastern Lake region, the Ohio Valley and the Rio Grande Valley had less sunshine than normal.

The relative humidity was above normal in much of the Middle Atlantic and New England area, and often near the east Gulf coast and near the Rio Grande. Practically all other districts had less humidity than normal, the shortage being large in the middle and northern portions of the Plateau and Rocky Mountain regions, in most of the Plains and in the upper Mississippi Valley.

SEVERE LOCAL STORMS, JULY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Fort Wayne, Ind.	1	12:25 p. m.			$1,700	Thunderstorm	Power lines damaged; traffic delayed; large building of lumber company blown down; windows broken.	Official U. S. Weather Bureau.
Goff (near), Kans.	1	12:30 p. m.	1,500		4,000	Tornado	Chief damage to large barn and small farm buildings; livestock killed or injured; path 1 mile long.	Do.
Indianapolis (near), Ind.	1	1 p. m.				do	Occurred near airport, no damage reported	Do.
Darlington, Wis., and vicinity.	1	5:30 p. m.	880		25,000	do	Character of damage not reported	Do.
Port Arthur, Tex.	1	6 p. m.		1	73,000	Thunderstorm	Lightning caused explosion and fire on oil barge	Do.
Bradford, Cumberland, Lancaster, Lebanon, and Dauphin Counties, Pa.	1	P. m.			300,000	Severe thunderstorm, wind and hail.	Many houses unroofed; heavy crop damage	Do.
Boone and Grundy Counties, Iowa.	1	P. m.			17,000	Wind and hail	Buildings and crops damaged	Do.
Tony (near), Wis.	1	P. m.			8,000	Tornado	Large barn destroyed and another damaged	Do.
Audubon, Black Hawk, Bremer, Carroll, Cerro Gordo, Clay, Greene, Guthrie, Hamilton, Hancock, Harrison, Kossuth, and Marion Counties, Iowa.	1					Wind	Crops flattened; buildings damaged; a few poles blown down.	Do.
Beattle, Kans.	1				500	Probably tornado	Barns and fruit trees damaged	Do.
Indianapolis, Ind.	1					Thunderstorm	2 houses struck by lightning; number of power and light poles damaged or blown down.	Do.
Marshall and Pocahontas Counties, Iowa.	1				55,000	Hail	Chief damage to crops	Do.
Maryland (central and western).	1					Wind	Trees blown down or broken off; buildings damaged.	Do.
Mounds, Ill.	1					do	Plate glass windows broken; trees, roofs, and small buildings damaged.	Do.
Pratt County, Kans.	1				50,000	do	Wheat badly twisted and blown down; minor damage to buildings.	Do.
Beckemeyer and Posey, Ill.	2	4 p. m.	4 mi.			do	Homes, outbuildings, and trees damaged; crops injured; path 10 miles long.	Do.
Buffalo, N. Y., and vicinity.	2				36,000	do	Buildings, hangar, and 5 planes damaged	Do.
Memphis, Tenn., and vicinity.	2				85,000	Thunderstorm	Schoolhouse and business building severely damaged.	Do.
Spearville (near), Kans.	2				5,000	Hail	Character of damage not reported; area about 5 square miles.	Do.
Tama County, Iowa	2				3,000	Wind	Barns and other small buildings damaged	Do.
Grand Junction, Colo.	3	5:04 – 5:13 p. m.	2 mi.		15,000	Hail	Damage chiefly to apples, melons, and tomatoes.	Do.
Sanders Connty, Mont.	3				1,500	do	Roofs, auto tops, etc., damaged	Do.
Wilson, Hazen, and Slovaktown, Ark.	3				20,000	Wind	Character of damage not reported	Do.
Brown and Jackson Counties, Kans.	4	2:30–3 p.m.	3 mi.		20,000	Hail	Details not reported; path 10 miles long	Do.
Barber, Harper, Sumner, Kingman, and Sedgwick Counties, Kans.	4	2:30 – 3:30 p. m.				Wind	Chief damage at airport at Wichita; path 80 miles long.	Do.
Rogers, Ark., and vicinity	7				15,000	Hail	Character of damage not reported	Do.
Hamilton, Webster, and Dubuque Counties, Iowa.	8	2:30–3 p.m.			48,000	Hail and wind	Considerable damage to buildings and crops	Do.
Tyrone (near), Okla	8	5 p. m.	1–2 mi.		25,000	Hail	Damage mainly to crops; path 4 miles long	Do.
Cooke, Grayson, Collin, and Fannin Counties, Tex.	8	P. m.			3,800	Wind	Buildings unroofed; crops hurt	Do.
Lyon and Story Counties, Iowa.	8	P. m.			40,000	Hail	Considerable crop loss	Do.
Albuquerque, N. Mex. (10 miles east).	9	12:15 p. m.				Probably tornado	No details reported	Do.
Alliance, Nebr.	9	2–3 p. m.	4 mi.		60,000	Hail	Considerable damage to crops and some loss of livestock; path 5 miles long.	Do.
Jonesville, Va.	9	3:30 p. m.	1.5 mi.		12,000	Hail and rain	Crops hurt; soil washed; buildings and bridges damaged.	Do.
Benton, Buchanan, Delaware, Dubuque, Franklin, Johnson, Linn, Mitchell, Polk, and Tama Counties, Iowa.	9				156,000	Hail	Crops total loss in some places; poultry killed	Do.
Pennsylvania (north central and northeastern).	9					Rain and electrical.	Cellars flooded; bridges washed away; heavy crop loss.	Do.
Waukesha County, Wis.	10				5,000	do	Considerable damage, chiefly to crops	Do.
Belleville to Cuba, Kans.	11	5 p. m.	2 mi.		8,000	Hail and wind	Trees broken; small buildings, poles, and wires blown down; path 4 miles.	Concordia Blade Empire (Kans.).

[1] "Mi." signifies miles instead of yards.

Severe local storms, July, 1931—Continued

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Rydal and Norway to Clifton and Greenleaf, Kans.	11	5 p. m.	15 mi.		$11,000	Wind	Chief damage to farm buildings and trees; path 40 miles long.	Official, U. S. Weather Bureau.
Cleburne to Fostoria, Kans.	11	6 p. m.	4 mi.		2,000	do	Barns and trees damaged	Do.
Casselton to Mapleton, N. Dak.	11					Hail	Heavy crop damage	Do.
Hamilton, Harrison, Jasper, Mills, and Pottawattamie Counties, Iowa.	11					do	Crops total loss in some localities	Do.
Gage and Jefferson Counties, Nebr.	12	3 p. m.	3-4 mi.		50,000	do	Crops, windows and roofs damaged; poultry killed; path 10 miles.	Do.
Fremont, Marshall, Page, Tama, and Wayne Counties, Iowa.	12				81,700	Wind and hail	Crops beaten; buildings and cars damaged; livestock killed.	Do.
Six Mile, S. C.	13	9 p. m.			12,000	Thunderstorm	Lightning caused fire, which destroyed store and contents.	Do.
Sky Harbor Airport, Tenn.	13				5,000	Wind	Hangar and trees damaged	Do.
Philadelphia, Pa., and vicinity.	14	7:30 p. m.			1,000,000	Electrical and rain	Parts of city severely damaged by water; damage by lightning in vicinity.	Do.
Alabama (southwestern)	14-15					Rain and wind	Bridges washed out; large areas inundated; traffic interrupted; telephone lines out of commission; crops damaged.	Do.
Moneta, Va.	14-15				2,000	2 severe hailstorms.	Character of damage not reported	Do.
Winnebago County, Ill.	15	12:45 a. m.	1,760		20,000	Wind	Buildings damaged; silos wrecked	Do.
Anne Arundel County, Md. (southwestern).	15	4 p. m.	880		1,000	Hail	Corn and tobacco hurt	Do.
Kent County, Md. (northwestern).	15	4 p. m.	2.5 mi.		25,000	do	Crops, chiefly corn and tomatoes, damaged	Do.
Richmond, Va.	15	5 p. m.			5,000	Wind and electrical.	Buildings damaged; trees suffered; telephones out of commission.	Do.
Davidsonville, Md., and vicinity.	15				4,000	Wind	2 barns and silo wrecked; many trees prostrated	Do.
Jenison, Mich.	15					Probably tornado, wind and hail.	2 barns wrecked; grain crops leveled; many trees uprooted.	Do.
Rockpoint, Md. (north of).	15					Hail	Considerable tobacco ruined	Do.
Phillips, Sheridan, and Valley Counties, Mont.	15-16				199,300	do	Extensive crop damage; much loss of livestock; buildings damaged.	Do.
Oakland, Md.	16	3-4 p. m.	200-880		300	Tornado	Minor damage to buildings; trees blown down	Do.
Richmond, Va.	16	5 p. m.			3,500	Wind and electric.	Telephone service disrupted; trees injured	Do.
Knoxville, Tenn.	16					Severe thunderstorm.	Some sections of city flooded; pavements torn up; traffic interrupted; some damage to buildings by lightning.	Do.
Morgan County, W. Va.	16					Hail	10,000 bushels of apples ruined	Do.
Pittsburgh, Pa.	16				25,000	Thunderstorm and wind.	Many small buildings unroofed; trees uprooted	Do.
Washington County, Md. (eastern).	16		1,760			Hail	Windows shattered; roofs pierced; grapevines, fruit and gardens injured; path 10 miles long.	Do.
Chambersburg, Pa.	17	2-2.30 p.m.		1	20,000	Electrical and rain	Property damaged chiefly by flooding	Do.
Sheboygan, Mich.	17	3.40-5 p.m.				Thunderstorm and wind.	Trees uprooted; small buildings overturned; other minor damage.	Do.
Jackson and O'Brien Counties, Iowa.	17				7,000	Hail and wind	Crops hurt; minor damage to buildings	Do.
Johnson City (near), Tenn.	17			2		Wind	Trees blown down at roadside fair; 8 persons injured.	Do.
Lisbon (near), Md.	17				3,500	Electrical	Barn and other outbuildings burned	Do.
Traverse City, Mich.	17				12,000	Wind squall	Blimp torn from mooring and damaged	Do.
Pana, Ill.	18			1		Electrical and wind	Barn burned; corn leveled over considerable area.	Do.
Wayne, Winneshiek and Linn Counties, Iowa.	19	P. m.			17,500	Wind, hail, and rain.	Crops and buildings damaged; sewers flooded	Do.
Chicago, Ill.	19					Thunderstorm	Streets and basements flooded; traffic delayed; trees uprooted.	Do.
Forestville and Sturgeon Bay, Wis., and vicinity.	19				50,000	Thunderstorm	Chief loss to cherry orchards	Do.
Simpsonville, S. C.	19				1,500	Electrical	Barn and contents destroyed	Do.
Brush, Hillrose, New Raymer, and Snyder, Colo.	20	5:30 - 8:30 p. m.	2-8 mi.	1	110,000	Hail and wind	Crops hurt; poultry and livestock killed; house wrecked, others damaged; light, telephone, and telegraph poles blown down.	Do.
Buffalo, N. Y.	20				75,000	Electrical	Yacht and soap factory set fire and 3 churches damaged.	Do.
Clint to Socorro, Tex.	20	2 p. m.	1.5 mi.			Hail	Crops injured 25 to 50 per cent	Do.
Winnsboro, S. C.	20	P. m.			3,000	Electrical	Building damaged	Do.
Marshall County, Ill. (northwestern).	21	3 p. m.	3 mi.		75,000	Hail	Heavy crop loss; path 4 miles	Do.
Quinlan, Tex.	21	3:45 p. m.	440		1,000	Tornado	Buildings damaged; path 1.5 miles long	Do.
Diamond Creek to Elmdale, Kans.	22	4-7 p. m.	1,760		6,000	Hail	Crops injured; path 5 miles long	Do.
Catlin, Ill., and vicinity	22	10 p. m.	4 mi.		190,000	do	Heavy loss to crops; considerable damage to buildings and other property; path 8 miles long.	Do.
Connecticut (northcentral).	22					do	Considerable damage to tobacco and other crops	Do.
Phillips and Roosevelt Counties, Mont.	22					Hail	Buildings and crops damaged; some loss of livestock.	Do.
Calhoun, Jersey, Macoupin, and Pike Counties, Ill.	22-23				423,500	Hail, wind, and electrical.	Crops severely damaged; schoolhouse and barn burned.	Do.
Montezuma and Port Byron districts, N. Y.	23	1:30 p. m.	3 mi.		32,000	Hail	Heavy damage to field crops and buildings	Do.
Ivy Depot, Va. (2 miles west of).	23	P. m.	1,320		5,000	do	Fruit and corn injured	Do.
Frederick and Washington Counties, Md.	23					do	Much injury to apple and peach crops	Do.
Snowflake to Taylor, Ariz.	23					Wind and hail	Crops almost total loss	Do.
Unionville, Md.	23				5,000	Electrical	Barn and contents burned	Do.
Stuttgart, Ark., and vicinity.	23-24				5,000	do	Damage to power lines and equipment	Do.
Norfolk, Va.	24	12:30 p. m.				Wind squall	Many windows broken; trees uprooted	Do.
Alexandria, La. (Camp Beauregard.)	24	4:30-5 p.m.			15,000	Thundersquall	2 buildings wrecked, 1 moved from foundation; number of tents blown down; airplane demolished; many persons injured.	Do.
Frederick County, Md. (south-central).	24	7 p. m.	880-1,760		20,000	Hail and wind	Windows and roofs pierced; corn stripped; fruit injured; trees uprooted; path 10 miles long.	Do.
Shawnee, Okla. (8 miles northwest).	24	8 p. m.	50			Tornado	Damage confined to a few farms	Do.
Conway, Ark.	24				3,000	Wind	Character of damage not reported	Do.
Humboldt County, Nebr. (Leonard Creek Ranch.)	24				1,500	Violent dust whirl.	Lambing shed wrecked	Do.

[1] "Mi." signifies miles instead of yards.

Severe local storms, July, 1931—Continued

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Tuckerton, Pa	24				$15,000	Electrical	No details reported	Official, U. S. Weather Bureau.
Maxwell (near), N. Mex	25		3 mi.		3,000	Hail	Crops hurt; path 8 miles	Do.
Middle Hope and Marlboro, N. Y.	27	5:45 p. m.	1,320		2,000	Wind squall and rain.	Vineyards damaged	Do.
Moorhead, Minn., to Fargo, N. Dak.	27				12,000	Wind and hail	Crops and buildings damaged	Do.
Ganado to Fort Defiance, Ariz.	28	6 p. m.	4 mi.	3	275,000	Hail and rain	Severe loss to crops and stock; buildings and irrigation dam damaged.	Do.
Bernville, Pa	29				10,000	Electrical	No details reported	Do.
Colchester and Winooski Valley, Vt.	29					Wind and rain	Trees and weak buildings blown down; crops hurt.	Do.
Lindrith, N. Mex	30					Hail and rain	Corn and bean crops considerably damaged	Do.
Pomeroy (near), Wash	30					Hail	Standing grain damaged 50 per cent	Do.
Fillmore and Saline Counties, Nebr.	31	2-3 p. m.	2 mi.		10,000	do	Damage to crops estimated at 50 per cent in places; path 16 miles long.	Do.
Dallas County, Iowa	31	2:30 p. m.			4,100	Wind and hail	Buildings and crops damaged	Do.
Harmony, Nebr	31	7 p. m.				Small tornado	A few outbuildings destroyed	Do.

[1] "Mi." signifies miles instead of yards.

RIVERS AND FLOODS

(River and Flood Division, Montrose W. Hayes in charge)

By RICHMOND T. ZOCH

The only overflows of consequence in the principal rivers of the United States during July, 1931, were those in the Pascagoula and Pearl River systems of Mississippi. These floods caused damage to the extent of $165,000, most of which was the result of 25,000 acres of prospective crops being inundated. The money value of property saved by warnings was estimated at $5,000.

The usual table of flood stages which occurred at Weather Bureau gaging stations appears herewith. No damage was reported at any of these places except that mentioned in the preceding paragraph.

Heavy local rains caused numerous overflows in creeks and small streams where it is impracticable to maintain warning service. Damages were reported (but the extent or amount was not given) at Bremen, Ohio, on July 2, at Cawker City, Kans., on July 6, in central Vermont on July 22, at Portsmouth, Ohio, on July 23, at Pocatello, Idaho, on July 29, and at Helena, Mont., and Cheyenne, Wyo., on July 30. On July 9 severe local rains caused floods in small streams in and around Scranton, Pa. The damage was estimated at $50,000. On July 14 a severe storm caused floods in the small streams in and around Philadelphia, Pa. The damage was estimated at $1,000,000.

The Mississippi River and nearly all of its tributaries remain at very low stages.

Table of flood stages in July, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Susquehanna: Oneonta, N. Y	12	11	11	12.0	11
Neuse: Smithfield, N. C	14	5	5	14.2	5
Santee: Rimini, S. C	12	13	13	12.2	13
EAST GULF OF MEXICO DRAINAGE					
Chickasawhay: Enterprise, Miss	21	28	30	22.1	29
Pearl: Jackson, Miss	20	28	31	22.3	31
MISSISSIPPI SYSTEM					
Red Basin.					
Sulphur: Ringo Crossing, Tex	20	26	26	20.4	26
WEST GULF OF MEXICO DRAINAGE					
Rio Grande:					
Riogrande, Tex	21	19	19	23.5	19
San Benito, Tex	23	20	22	24.7	21
Brownsville, Tex	18	21	22	18.5	22
GULF OF CALIFORNIA DRAINAGE					
Colorado: Parker, Ariz	7	1	1	7.0	1
	-----	8	14	7.2	9–11

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

By the Marine Division, W. F. McDONALD in charge

NORTH ATLANTIC OCEAN

By W. F. McDONALD

The average barometric pressures over the Atlantic and its adjacent coasts during July, 1931, did not depart greatly from the monthly normals except over Iceland, the British Isles, and Scandinavia, where the barometer averaged considerably below normal. From Halifax to the Spanish Peninsula there was a slight excess in average air pressure, and a slight deficiency from the Caribbean region to Bermuda and New England. (See Table 1.)

These conditions represent a displacement northeastward of the Atlantic centers of action during July, with some intensification of the usually inactive center of low pressure over the northeastern Atlantic, which is reflected in the fact that the British Isles experienced unusually cloudy and unsettled weather.[1] The pressure over southern Greenland (Julianehaab) continued above normal though not up to the extraordinary height shown by average pressure in the preceding month when the mean barometer was 30.07 inches.

[1] Monthly Supplement to the Daily Weather Report. British Meteorological Office July, 1931.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, July, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland [1]	29.94		30.32	9th	29.53	1st.
Reykjavik, Iceland [1]	29.71	−0.12	30.10	7th	29.36	23d.
Aberdeen, Scotland [2]	29.68	−.24	[3] 30.01	1st	[3] 29.33	27th.
Valentia, Ireland [2]	29.83	−.18	[3] 30.20	21st	[3] 29.52	14th.
Lisbon, Portugal [1]	30.07	+.05	30.30	25th	29.94	22d.
Madeira [1]	30.11	−.02			29.95	22d.
Horta, Azores [1]	30.34	+.07	30.52	1st	30.08	10th.
Belle Isle, Newfoundland [1]	29.83	−.04	30.38	8th	29.38	5th.
Halifax, Nova Scotia [1]	29.96	+.01	30.26	10th	29.62	31st.
Nantucket [2]	29.93	−.05	30.13	13th	29.52	22d.
Hatteras [2]	29.96	−.05	30.16	14th	29.75	22d.
Bermuda [1]	30.09	−.04	30.28	25th	29.86	4th.
Turks Island [1]	30.05	−.02	30.18	12th	29.96	1st.
Key West [2]	29.97	−.06	30.10	20th	29.85	9th.
New Orleans [2]	29.96	−.04	30.15	30th	29.73	15th.

[1] All data based on a. m. observations only, with departure computed from best available normals related to time of observation.
[2] Corrected 24-hour means, based on more than one observation daily.
[3] Highest and lowest from one observation daily (a. m. only).

Reports in hand indicate that gales were experienced on only a few days in the month. The most disturbed conditions occurred over the main northern steamship routes east of longitude 45° W. during the latter half of the month, with three ships reporting winds of gale force in that area on the 16th and three on the 20th or 21st. These spells of mildly stormy conditions were the result of the development of an extensive low-pressure belt reaching from Labrador to the North Sea with a stable ridge of high pressure extending from Florida to Spain and crested well northward over the Azores.

The French steamship *Nevada* (captain, F. Bougouin; observer, LeFichoux) on the 14th encountered a small, sharp depression at the western end of the English Channel, in which the barometer dropped between noon and 7 p. m. from a reading of 29.9 to 29.1 inches, after which the pressure rose rapidly, the depression being accompanied by wind rising briefly to force 10, and shifting from east-northeast to west-northwest. This disturbance is clearly identified in the daily weather maps of the region, which show it to have traveled northeastward, retaining its central depth but increasing in area, though apparently not producing storm winds of any great extent.

A disturbance resembling in some of its characters a mild tropical cyclone originated in the western Gulf of Mexico on the 14th and caused winds of force 8 to 11 near the Louisiana coast as it progressed northeastward on the 14th and 15th. The tanker *W. C. Teagle* (captain, W. Doyle; observer, C. Dwyer) encountered this disturbance en route from Galveston through the Florida Straits, on the afternoon of the 14th, about latitude 28° N. and longitude 91° W. The barometer fell rather sharply about two-tenths of an inch, reaching the lowest point at 4:30 p. m., when the ship's weather journal states that "the wind was ESE., force 11, with driving rain squalls and the air full of spray. Kept the vessel head-on at reduced speed. At 6 p. m. the wind was SE., force 10, with barometer pumping between 29.72 and 29.78." Southeast gale and rain continued throughout most of the night of the 14th–15th, but the wind changed to south by 7 a. m. and diminished to force 6, with barometer returning to approximately the same height as at the beginning of the storm. The intensity of the disturbance may be judged, however, by the remark in the storm log that "the vessel was set north about 50 miles by wind and sea."

A wind of moderate gale force was experienced by the steamship *LaPlaya* in the Gulf of Honduras on the 23d, but this appears to have been the result of a local strengthening of the trade wind rather than a developing tropical disturbance.

Fogs were as prevalent as usual for July over the main steamer routes from North Atlantic ports eastward and northeastward, being most widespread between the 5th and 10th and again from the 22d to 28th, during which periods fog blanketed most of the Atlantic area north of latitude 40° and eastward to the vicinity of longitude 20° W., with a considerable extension southward along the American coast to the latitude of Hatteras from the 7th to 9th. There was another spell of extensive fogs over the mid-Atlantic between the 15th and 19th, but American waters were quite free between the 17th and 21st and again in the last five days of the month.

Three successful airplane crossings of the Atlantic were attempted during July. The first plane (Magyar and Endres) left the American coast on the 15th, landing near Budapest on the 16th. Two planes (Boardman and Polando in one, Herndon and Pangborn in the other) left simultaneously on the 28th, the first named making a nonstop flight from New York to Constantinople by which they claimed to have established a new mark for distance, in a traveling time of somewhat over 49 hours of flight. The second plane landed safely at Berlin.

It may be noted here that these flights were favored by stable barometric situations over the Atlantic, marked in each case by a well-developed ridge of high pressure extending completely across the ocean with long, almost straight, isobars parallel to the line of flight, creating steady tail winds over practically the entire stretch of ocean route. Charts VIII to XI reproduce the weather maps of the North Atlantic on July 15, 16, 28, and 29, for their interest in connection with these trans Atlantic flights.

OCEAN GALES AND STORMS, JULY, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Lochkatrine, Br. M. S.	Panama Canal.	Liverpool	27 56 N	58 16 W	July 1	4 p., 1	July 1	30.02	SSE	SSE, 8	SSE	SSE, 8	Steady.
Narragansett, Br. M. S.	Liverpool	Panama Canal.	48 48 N	18 33 W	July 3	6 p., 3	July 4	29.85	WSW	W, 6	WSW	WNW, 8	WSW-WNW.
Nevada, Fr. S. S.	Havre	do	49 00 N	2 00 W	July 14	7 p., 14	July 15	29.00	ESE	NNW, 10	NW	NNW, 10	
W. C. Teagle, Am. S. S.	Galveston	Cape Henry	27 44 N	90 42 W	do	4 p., 14	do	29.70	ESE	ESE, 11	SSE	ESE, 11	ESE-S.
Ambridge, Am. S. S.	Antwerp	New York	49 04 N	39 07 W	July 16	5 a., 16	July 17	29.78	WSW	SSW	SW	WSW, 9	SSW-WSW.
Gonzenheim, Ger. S. S.	Rotterdam	do	50 40 N	23 02 W	do	11 p., 16	do	29.89	W	W, 8	NW	W, 8	WSW-WNW.
Do	do	do	49 36 N	39 52 W	July 19	6 a., 20	July 20	29.81	S	SSW, 9	WSW	SSW, 9	SSW-WSW.
City of Alton, Am. S. S.	do	do	50 30 N	15 46 W	July 16	Mid., 16	July 17	29.96	W	W	SW	SW, 8	W-SW.
Do	do	do	48 45 N	38 25 W	July 20	2 a., 21	July 21	29.76	SW	SW	WNW	W, 8	SW-WNW.
Delfshaven, Du. S. S.	Antwerp	Baltimore	42 37 N	46 37 W	July 18	7 a., 19	July 19	30.08	S	S, 9	SW	SW, 9	S-SW.
Bird City, Am. S. S.	Copenhagen	Portland, Me.	56 55 N	30 00 W	July 21	Mid., 21	July 22	29.36	W	W, 5	WSW	W, 8	
La Playa, Pan. S. S.	Mobile	Puerto Cortez.	17 16 N	87 20 W	July 23	6 p., 23	July 24	29.78	ENE	NE, 7	ENE	ENE, 8	Steady.
Collamer, Am. S. S.	Bordeaux	New York	47 21 N	48 12 W	July 31	7 p., 31	Aug. 1	29.25	S	SSW, 9	WSW	SSW, 9	S-WSW.
NORTH PACIFIC OCEAN													
Golden Sun, Am. S. S.	San Francisco	Yokohama	44 00 N	151 30 W	July 2	6 p., 2	July 2	30.16	SSE	SSW, 8	SSW	SSW, 8	SSE-SSW.
Shintoku Maru, Jap. Bk.	Kobe	Honolulu	46 43 N	164 10 E	July 2	2 p., 3	July 4	29.79	SE	SE, 7	E	SE, 8	Steady.
Makiki, Am. S. S.	Hilo	San Francisco	36 00 N	127 00 W	do	5 a., 4	do	29.84	N	NNW, 6	NNW	NNW, 8	Do.
Emidio, Am. S. S.	San Pedro	Vancouver	39 40 N	124 24 W	July 3	2 p., 3	July 3	29.86	NNW	NNW, 7	NNW	NW, 8	
Challenger, Am. M. S.	Balboa	San Diego	16 20 N	99 57 W	do		do	29.55	E	E, 9	W	E, 9	E-W.
Ogura Maru, Jap. M. S.	Yokohama	Los Angeles	42 43 N	177 22 W	July 7	4 p., 8	July 8	29.42	ESE	NNE, 8	N	NE, 8	
Hanover, Am. S. S.	San Pedro	Kobe	32 35 N	140 25 E	July 9	11 a., 9	July 9	29.66	W	W, 8	W	W, 8	Steady.
San Diego Maru, Jap. M. S.	Yokohama	San Pedro	41 46 N	165 34 W	do	8 p., 9	July 10	29.33	E	E, 8	E	E, 8	Do.
Akagisan Maru, Jap. M. S.	do	San Francisco	42 47 N	157 50 E	do	Noon, 9	July 11	29.60	E	NNE, 2	ENE	ENE, 8	E-NNE.
Charcas, Am. S. S.	Buenaventura	San Pedro	15 00 N	96 00 W	July 10	2 p., 10	July 10	29.66	N	N, 7	SE	N, 8	
Atlantic, Am. S. S.	San Francisco	Panama	18 51 N	104 42 W	July 21	10 a., 21	July 21	29.84	SE	SSE, 5	SE	SE, 8	SE-SSE.
Elfina, Am. S. S.	San Pedro	do	[1]15 00 N	[1]97 30 W	July 26	7 a., 26	July 26	29.63	NE	NE	SSE	NNE, 8	
Nora, Am. S. S.	do	Balboa	16 03 N	98 48 W	do	1 p., 26	do	29.67	ENE	ENE, 7	SE	E, 8	E-ESE.

[1] Position approximate.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—While in June, 1931, the Aleutian LOW was better developed than normal for the month, in July, on the average, the depression had largely filled, with barometer higher than normal, except over the northwestern part of the Gulf of Alaska, where it was slightly below. Such shallow northern depressions as occurred extended from near Kodiak northward across Alaska into the Arctic Ocean, the average barometer at Point Barrow being 29.84 inches.

The North Pacific HIGH on the average covered a wide expanse of the ocean, with a greatest north-south extent from the central Bering Sea to the Hawaiian Islands, and a greatest northeast-southwest extent from eastern Alaska almost to the lower islands of Japan.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, July, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	29.84	−0.08	30.26	1st	29.44	30th.
Dutch Harbor [1]	30.02	+0.08	30.30	4th	29.64	26th.
St. Paul [1] [2]	30.00	+0.16	30.30	1st	29.66	24th.
Kodiak [1]	29.92	−0.02	30.20	4th [3]	29.42	17th.
Midway Island [1]	29.99	−0.12	30.10	11th [3]	29.80	7th. [3]
Honolulu [4]	30.01	−0.01	30.09	2d	[3] 29.90	31st.
Juneau [4]	30.05	0.00	30.43	5th	29.52	20th.
Tatoosh Island [4] [5]	30.04	−0.04	30.45	3d	29.69	20th.
San Francisco [4] [5]	29.84	−0.11	30.02	8th	29.67	24th.
San Diego [4] [5]	29.81	−0.11	29.93	9th	29.69	24th.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 30 days.
[3] And on other date or dates.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—The month of July passed without the appearance of any important cyclones on our charts over any part of the North Pacific Ocean. Aside from one or two Aleutian disturbances of moderate depth, the deepest depression occurring in middle and upper latitudes passed over northern Japan on the 26th. No high winds, however, so far as known, occurred in its vicinity. Scattered gales, in no instance exceeding force 8, were reported on a few days from the 2d to the 11th along the upper routes. A fresh gale was experienced south of Honshu on the 9th, while off the upper California coast and thence for approximately 500 miles southwestward, gales of similar force were encountered on the 2d and 3d. In the last instance the cause was a sharp pressure gradient on the eastern slope of the oceanic HIGH abutting upon a LOW over southern California.

Conditions were quiet in the Asiatic Tropics, with only slight depressions occurring. Off the Mexican west coast the weather was considerably disturbed, with indications that at least four tropical depressions or cyclones of sufficient energy to cause known gales of force 8 or 9 were developed. Observations were too limited, however, to give more than meager information as to storm formation and movement. The only disturbance among them mentioned by the Mexican weather maps was that of the 21st to 24th or 25th, with some violence of wind and precipitation indicated, as the cyclone progressed northwestward and entered the coast through the Gulf of California. The gale notations, some of which appear in the table of gales, as gathered from our vessel weather reports, show the following: On the 3d, south of Acapulco, occurred the highest wind thus far reported for the entire ocean for the mouth—an east gale of force 9, accompanied by a barometer depressed to 29.55 inches. On the 10th, at the western extremity of the Gulf of Tehuantepec, a fresh north gale occurred, with pressure down to 29.66 inches. On the 21st a fresh southeast gale was reported south of Manzanillo, with but slight barometric depression. On the 23d, in 16° 55′ N., 101° 35′ W., a moderate southeast gale was experienced, with lowest pressure 29.59 inches. At 9 p. m. of the 25th the American steamship *Ensley City* reported a barometer reading of 29.39, and an hour later a maximum wind force of 7 from the southwest in 13° 20′ N., 96° 08′ W. On the 26th, between Acapulco and Salina Cruz, fresh gales from east-southeast and north-northeast occurred, with lowest reported barometer, 29.63 inches. In a report from the American steamship *La Perla*, the observer, Mr. J. Walton, said: "July 21 and 22: Unsettled weather conditions along the Mexican coast. The Weather Bureau at Mexico advised that a hurricane was moving along the coast."

Winds at Honolulu.—The prevailing wind direction at Honolulu was east, with a maximum velocity of 24 miles from the northeast on the 21st.

Fog.—Over practically the entire region lying between the fortieth and fiftieth parallels fog showed a slight to heavy increase over that of June, the percentage of its occurrence rising gradually from the American coast westward toward the Kuril Islands. Over most of the western half of the ocean within these latitudes at least 40 to 60 per cent of the days had fog. Fog lessened rapidly south of the fortieth parallel, disappearing mainly at 35° N., except along the American coast. From Eureka southward to the middle coast of Lower California it occurred on 25 to 30 per cent of the days.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for July of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the July, 1930, means from the 11-year means for July, 1920–1930, and the changes from the temperatures for the preceding month of June, 1930.

The chart shows the number of observations taken during the month of July, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

[1] In three cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

There is usually a slight increase during July in the surface temperatures of the Straits of Florida and the Caribbean Sea. The average rise is greatest in the straits during the first part of the month, and in the Caribbean near its end. In both areas the rise is least in the middle half of July, at which time the average temperatures show practically no change from one quarter-month to the next. Both areas are warmest later in the summer, the peak monthly and quarter-monthly averages occurring in August or in September.

The northwestern portion of the Caribbean Sea is warmer in July than the southern and eastern parts, and the coolest water is that off the coast of Venezuela. There is thus, during this month, a roughly progressive increase of temperature in the Caribbean from east to west and from south to north.

The northwestern waters of the Caribbean, in addition to being the warmest, also show the greatest June to July rise in temperature of any portion of the sea, while the southern salient of the Caribbean, bounded on the north by the line extending from Gallinas Point, Colombia, to Cape Gracias a Dios, Nicaragua, and on the south by the continents, cools slightly from June to July. The rest of the sea shows little or no clearly defined temperature range between the two months.

TABLE 1.—*Lengths of "quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1-7	8-14	15-21	22-28
29 days	1-7	8-14	15-21	22-29
30 days	1-7	8-15	16-22	23-30
31 days	1-7	8-15	16-23	24-31

In July, 1930, the Caribbean Sea had a temperature near to or somewhat below the seasonal average from the seventieth meridian eastward, and was warmer than average over the rest of the area. The general average temperature, inclusive of the entire Caribbean Sea, was above the 11-year mean. These above-normal temperatures in the Caribbean had now persisted since March, 1930, or for five consecutive months.

The temperature of the Straits of Florida was close to the average except during the first quarter of July, when the region was cooler than is usual so late in the season.

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for July, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean	Number of observations	Mean
		°F.		°F.
1919 [1]	88	81.4	18	82.4
1920	238	81.1	37	82.4
1921	277	81.2	68	82.6
1922	191	81.0	63	82.9
1923	358	81.2	89	82.8
1924	334	81.8	100	84.2
1925	552	81.5	121	83.2
1926	536	82.5	155	84.0
1927	654	82.2	226	83.9
1928	682	81.9	183	84.0
1929	723	81.6	202	82.1
1930	[2] 702	82.0	[3] 170	83.0
Mean (1920–1930)		81.6		83.1

[1] Not used in computations because of insufficient data available.
[2] Includes 7 intake readings.
[3] Includes 2 intake readings.

TABLE 3.—*Mean sea-surface temperatures (°F.), and number of observations, July, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	July 1-7	161	81.8			37	82.3		
II	July 8-15	193	81.9			44	83.0		
III	July 16-23	170	82.2			50	83.2		
IV	July 24-31	178	82.0			39	83.3		
Month		[1] 702	82.0	+0.4	+0.5	[1] 170	83.0	−0.1	+2.6

[1] See notes 2 and 3, Table 2.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1931

[For description of tables and charts, see Review, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	81.8	+1.6	2 stations	104	[1] 2	Riverton	58	11	5.74	+0.37	Seven Hills	25.10	Tallassee	1.16
Arizona	83.7	+2.5	Quartzsite	119	2	Bright Angel[2]	38	5	2.28	−0.17	San Vicente	7.54	Marinette	0.00
Arkansas	81.0	+0.8	2 stations	106	2	Dutton	48	6	6.00	+2.25	White Cliffs	13.00	Morrilton	2.13
California	77.2	+4.2	Greenland Ranch	126	[1] 19	Madeline	30	[1] 1	0.04	−0.05	Lake Sebrina	1.48	182 stations	0.00
Colorado	69.7	+2.7	Las Animas	109	22	3 stations	20	[1] 7	1.42	−0.91	North Lake	4.51	Nast	0.08
Florida	82.8	+1.5	Monticello	106	3	Plant City	60	2	5.88	−1.27	Lake City	12.26	Fernandina	1.29
Georgia	83.1	+3.2	2 stations	108	[1] 2	Clayton	58	23	4.75	−1.00	Albany	10.57	Double Branches	1.77
Idaho	71.0	+2.4	Orofino	116	20	3 stations	25	[1] 1	0.30	−0.27	Blackfoot	1.42	7 stations	0.00
Illinois	79.1	+3.0	Sparta	108	1	Mount Carroll	46	[1] 8	2.92	−0.34	Hoopeston	9.39	Anna	0.42
Indiana	78.4	+3.1	Edwardsport	108	2	Marengo	43	11	3.08	−0.30	Butlerville	8.99	Monticello (near)	0.63
Iowa	77.2	+3.5	Lenox	109	28	Fayette	42	10	2.72	−1.11	Columbus Junction	7.87	Lansing	0.58
Kansas	80.4	+2.1	Russell	113	22	3 stations	43	[1] 5	2.32	−1.03	La Cygne	9.16	Richfield	T.
Kentucky	79.9	+3.1	Greensburg	104	31	2 stations	51	12	3.85	−0.29	Oneonta	9.51	Marion	0.45
Louisiana	82.9	+1.2	Dodson	105	[1] 2	Robeline	62	[1] 9	6.22	+0.10	Pearl River	14.56	Logansport	0.68
Maryland-Delaware	77.6	+2.4	Cumberland, Md	103	1	Sines, Md	44	26	4.53	+0.32	Keedysville, Md	8.48	Pocomoke City, Md.	1.95
Michigan	72.5	+3.8	Hastings	105	1	Sidnaw	32	10	1.77	−1.10	Ishpeming	5.93	Scottville	0.25
Minnesota	72.3	+3.2	Beardsley	112	15	Big Falls	36	9	2.31	−1.09	Gonvick	5.55	Farmington	0.57
Mississippi	81.3	+0.3	Austin	105	1	2 stations	59	[1] 11	8.91	+3.89	Hickory	17.65	2 stations	4.01
Missouri	80.3	+3.0	Clinton	110	29	Dean	49	6	3.23	−0.77	Lockwood	8.66	Birchtree	0.43
Montana	68.5	+2.1	2 stations	110	[1] 21	Conways Ranch	24	1	1.67	+0.16	Valier	5.28	Ballantine	0.23
Nebraska	77.5	+2.8	Minden	111	22	Gordon	37	7	1.92	−1.42	Fairbury	5.30	Lyman	0.00
Nevada	78.2	+4.8	Logandale	119	25	2 stations	33	[1] 5	0.14	−0.21	Sharp	1.23	8 stations	0.00
New England	71.1	+2.1	2 stations	99	28	Somerset, Vt	41	26	4.24	+0.50	Cavendish, Vt	11.30	Lewiston, Me	1.51
New Jersey	76.6	+3.0	Runyon	102	1	Runyon	50	27	4.24	−0.29	Lambertville	7.55	Cape May	0.80
New Mexico	72.4	+0.7	Orogrande	108	28	2 stations	28	[1] 5	2.56	−0.21	Dunagans Ranch	10.12	Pasamonte	0.27
New York	72.6	+3.1	Geneva	104	2	Indian Lake	41	6	5.39	+1.46	Conklinville	12.47	Bardonia	1.89
North Carolina	79.3	+2.4	Fayetteville	106	2	2 stations	46	[1] 6	6.07	+0.23	Raleigh	12.36	Asheville	2.09
North Dakota	70.6	+2.2	3 stations	111	[1] 25	Linton	37	5	3.03	+0.61	Petersburg	5.36	Power	0.18
Ohio	77.2	+3.9	Circleville	105	16	Millport	44	12	3.77	−0.07	Circleville	7.73	Catawba Island	0.52
Oklahoma	82.9	+1.4	2 stations	109	4	Boise City	44	5	2.99	+0.29	Wichita National Forest.	9.59	Kenton	0.31
Oregon	68.7	+2.4	Umatilla	115	20	Seneca	21	1	0.01	−0.39	Seaside	0.33	87 stations	0.00
Pennsylvania	75.2	+3.2	2 stations	105	[1] 1	Ridgway	39	11	5.28	+0.99	Center Hall	13.28	New Castle	1.81
South Carolina	82.2	+2.4	Garnett	107	7	Caesars Head	58	11	5.35	−0.51	Chappells	9.20	Ellenton	2.03
South Dakota	77.0	+4.7	Redfield	116	15	Pollock	39	5	1.46	−1.31	Ludlow	3.89	Onida	0.08
Tennessee	80.2	+2.8	Etowah	105	3	Crossville	50	[1] 11	4.82	+0.44	Elkmont	14.70	Ashwood	1.24
Texas	83.0	0.0	Henrietta	108	[1] 2	Dalhart	50	5	3.08	+0.48	Corpus Christi	11.92	Brownwood	0.23
Utah	75.4	+3.9	2 stations	112	[1] 24	2 stations	28	[1] 5	0.79	−0.13	Cedar City	3.20	Wendover	T.
Virginia	78.2	+3.0	Lincoln	104	1	Burkes Garden	45	11	5.35	+0.84	Wallaceton	11.37	Bedford	1.73
Washington	67.6	+1.1	2 stations	112	20	Wilbur	30	1	0.16	−0.46	Big Four	1.49	31 stations	0.00
West Virginia	76.8	+4.0	Charleston	108	3	Bayard	42	12	4.78	+0.12	Charleston	10.74	St. Marys	0.93
Wisconsin	73.4	+4.0	2 stations	106	[1] 16	Coddington	35	24	2.09	−1.59	Sheboygan	5.04	Downing	T.
Wyoming	68.6	+2.9	Colony	111	25	Hunters Station	21	7	1.32	−0.09	Pathfinder	5.37	Deaver	0.10
Alaska [June]	51.7	−1.2	Anchorage	92	26	White Mountain	20	1	1.49	−0.15	Kodiak	7.70	2 stations	T.
Hawaii	74.8	+0.5	3 stations	92	[1] 4	Kanalohuluhulu	48	7	7.20	+1.09	Puohakamoa (No. 2)	30.40	do	0.00
Porto Rico	79.7	+0.9	San German	98	26	Guineo Reservoir	56	19	7.39	+0.64	San Lorenzo	14.68	Ponce	1.87

[1] Other dates also.

[2] Ranger station.

TABLE 1.—*Climatological data for Weather Bureau stations, July, 1931*

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Max. velocity direction	Max. velocity date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							70.9	+2.0										82	3.96	+0.5										5.9		
Eastport	76	67	85	29.84	29.92	−0.01	61.0	+0.6	83	29	69	45	2	53	29	58	56	88	4.82	+1.7	14	5,078	s.	24	s.	6	2	10	19	7.6	0.0	0.0
Greenville, Me	1,070	6	----	28.76	29.91	------	67.7	------	88	29	77	47	18	58	30	62	----	85	7.20	------	19	3,561	se.	20	nw.	31	5	15	11	----	0.0	0.0
Portland, Me	103	82	117	29.79	29.91	−.04	69.6	+1.5	05	29	77	56	18	62	27	63	60	78	2.72	−0.5	16	4,990	s.	24	sw.	20	14	10	7	4.7	0.0	0.0
Concord	289	70	79	29.60	29.90	−.06	71.6	+3.1	95	28	82	51	13	62	36	----	----	----	4.02	+0.5	14	3,127	se.	17	nw.	31	7	12	12	6.1	0.0	0.0
Burlington	403	11	48	29.46	29.88	−.06	72.2	+1.9	96	1	81	54	18	63	30	----	----	----	6.91	+3.4	16	5,140	s.	35	s.	6	3	13	15	6.8	0.0	0.0
Northfield	876	12	60	------	29.90	−.04	69.0	+3.1	94	1	80	49	13	57	36	----	----	82	5.10	+1.5	14	3,805	s.	25	sw.	29	2	24	5	6.0	0.0	0.0
Boston	125	106	165	29.78	29.91	−.05	74.0	+2.3	97	28	81	60	4	67	25	66	63	72	2.43	−1.1	9	4,796	sw.	23	nw.	31	4	18	9	6.0	0.0	0.0
Nantucket	12	14	90	29.92	29.93	−.05	69.4	+1.6	89	28	75	54	1	64	21	66	65	90	5.88	+3.0	10	9,111	sw.	30	sw.	29	9	10	12	5.5	0.0	0.0
Block Island	26	11	46	29.89	29.92	−.05	70.0	+1.6	88	28	75	58	2	65	18	67	65	89	2.11	−1.0	14	8,351	s.	36	sw.	22	8	15	8	5.9	0.0	0.0
Providence	160	215	251	29.75	29.92	−.05	73.7	+0.3	94	28	82	59	2	66	25	68	65	79	3.03	−0.2	13	6,310	nw.	25	nw.	31	8	13	10	5.4	0.0	0.0
Hartford	159	122	----	29.75	29.92	−.05	75.0	+3.4	96	28	84	58	26	66	26	----	----	----	2.51	−1.9	10	------	sw.	----	------	----	6	16	9	6.1	0.0	0.0
New Haven	106	74	153	29.81	29.92	−.05	74.6	+2.8	95	28	82	61	26	67	26	68	65	77	3.99	−0.3	13	4,802	s.	31	nw.	24	10	13	8	5.5	0.0	0.0
Middle Atlantic States							77.8	+2.9										76	4.91	+0.6										5.4		
Albany	97	107	115	29.80	29.90	−.06	76.0	+3.4	97	28	85	59	26	67	28	67	64	71	5.76	+2.3	15	4,181	s.	23	s.	20	17	9	5	4.1	0.0	0.0
Binghamton	871	10	84	29.01	29.92	−.05	74.0	+4.0	98	1	84	53	13	64	32	----	----	----	5.71	+2.0	15	2,949	w.	22	n.	29	4	12	15	6.8	0.0	0.0
New York	314	414	454	29.58	29.91	−.07	76.5	+2.7	94	28	83	63	3	70	19	68	65	74	4.55	+0.3	14	7,333	sw.	48	nw.	29	4	16	11	6.5	0.0	0.0
Bellefonte	1,050	5	36	28.84	29.93	------	73.1	------	90	1	85	48	12	61	36	67	65	79	4.53	------	13	------	sw.	----	------	----	8	13	10	6.0	0.0	0.0
Harrisburg	374	94	104	29.54	29.93	−.05	77.9	+3.1	100	1	87	60	12	69	26	69	65	70	3.89	+0.1	14	3,519	w.	24	nw.	23	9	15	7	4.8	0.0	0.0
Philadelphia	114	123	367	29.81	29.92	−.06	79.8	+3.6	98	1	88	67	4	72	24	70	66	68	7.99	+3.8	11	6,984	sw.	53	n.	14	9	13	9	5.6	0.0	0.0
Reading	325	81	98	29.58	29.92	------	78.0	+2.5	99	1	88	61	12	68	28	69	65	70	4.55	+0.3	13	3,207	nw.	19	nw.	29	9	13	9	5.1	0.0	0.0
Scranton	805	111	119	29.09	29.93	−.05	75.0	+3.3	97	1	85	54	13	65	32	68	64	72	8.74	+4.7	13	3,368	sw.	21	nw.	29	5	19	7	6.0	0.0	0.0
Atlantic City	52	37	172	29.86	29.91	−.07	76.7	+4.6	93	15	83	65	3	71	20	71	68	81	1.67	−2.3	5	8,874	s.	37	se.	6	7	20	4	5.1	0.0	0.0
Cape May	17	13	40	------	------	------	76.9	+3.5	93	15	84	63	26	70	21	71	69	84	0.80	−3.0	9	------	se.	----	------	----	5	22	4	----	0.0	0.0
Sandy Hook	22	10	55	29.88	29.90	------	76.6	------	94	28	83	64	3	70	22	71	68	82	2.44	−2.7	14	6,953	sw.	36	w.	29	6	16	9	5.3	0.0	0.0
Trenton	190	159	183	29.72	29.92	------	77.5	+2.1	96	28	86	63	3	68	27	69	66	72	5.47	+1.5	9	5,055	sw.	31	nw.	14	10	10	11	5.7	0.0	0.0
Baltimore	123	100	215	29.79	29.91	−.07	81.0	+3.8	101	1	90	67	11	72	25	71	67	68	6.04	+1.4	14	5,280	sw.	50	ne.	1	10	14	7	4.9	0.0	0.0
Washington	112	62	85	29.81	29.92	−.08	79.6	+2.8	07	29	89	64	26	70	.27	71	68	75	4.23	−0.5	16	2,844	sw.	32	e.	1	10	13	8	4.8	0.0	0.0
Cape Henry	18	8	54	29.91	29.93	------	79.1	+1.6	98	30	86	65	27	72	25	73	72	82	6.47	+1.1	12	5,997	sw.	64	nw.	1	11	12	8	5.2	0.0	0.0
Lynchburg	681	153	188	29.22	29.94	−.07	80.2	+2.7	99	31	91	63	11	70	27	72	69	74	5.37	+1.2	17	2,960	w.	26	n.	10	13	15	3	4.5	0.0	0.0
Norfolk	91	170	205	29.85	29.94	−.06	80.6	+1.9	96	30	89	68	24	72	25	73	70	78	4.56	−1.2	11	6,528	s.	38	ne.	16	10	11	10	5.4	0.0	0.0
Richmond	144	11	52	29.80	29.04	−.07	80.4	+1.9	100	30	90	66	12	70	28	73	70	79	4.47	−0.3	15	3,706	sw.	28	e.	15	8	17	6	5.1	0.0	0.0
Wytheville	2,304	49	55	27.67	29.95	−.06	74.1	+1.5	94	2	85	51	11	63	32	68	66	81	5.68	+1.7	21	2,922	w.	17	ne.	9	6	18	7	5.7	0.0	0.0
South Atlantic States							81.8	+2.7										77	5.49	−0.3										5.3		
Asheville	2,253	89	104	27.71	29.97	−.05	76.6	+4.9	93	2	88	61	23	65	27	68	66	82	2.09	−2.2	15	2,953	nw.	26	se.	9	8	20	3	4.7	0.0	0.0
Charlotte	779	55	62	29.15	29.96	−.06	82.5	+4.1	101	2	93	67	15	72	28	72	70	75	8.62	+3.5	14	2,042	sw.	23	se.	15	7	19	5	5.3	0.0	0.0
Greensboro	886	6	56	29.03	29.97	------	79.8	------	98	2	90	63	11	69	27	72	70	80	5.22	------	12	3,632	sw.	38	nw.	7	6	18	7	5.7	0.0	0.0
Hatteras	11	5	50	29.94	29.96	−.05	78.6	+0.4	89	19	85	68	28	72	17	75	73	84	4.82	−0.7	11	6,610	sw.	46	nw.	18	11	14	6	4.9	0.0	0.0
Raleigh	376	103	146	29.56	29.95	−.06	81.4	+2.6	98	30	91	68	11	72	27	73	71	76	12.36	+7.0	10	3,958	sw.	28	nw.	18	6	18	7	5.8	0.0	0.0
Wilmington	78	81	91	------	29.98	−.03	81.8	+2.7	96	7	90	69	27	74	23	----	----	82	6.33	−0.8	14	3,966	sw.	21	ne.	17	8	19	4	----	0.0	0.0
Charleston	48	11	92	20.93	29.98	−.05	82.9	+1.5	101	2	90	70	11	76	27	77	75	79	6.88	0.0	15	5,772	sw.	34	n.	2	7	11	13	5.9	0.0	0.0
Columbia, S. C	351	41	57	29.59	29.96	−.06	82.8	+1.9	101	2	93	67	26	72	31	73	70	74	5.55	+0.2	11	3,653	sw.	46	ne.	2	9	21	1	4.5	0.0	0.0
Due West	711	10	55	29.24	29.99	------	81.9	------	99	3	92	68	27	71	26	----	----	----	3.94	------	12	4,031	sw.	32	nw.	21	5	18	8	5.7	0.0	0.0
Greenville, S. C	1,039	139	146	28.90	29.06	------	81.5	+4.6	99	3	92	65	11	71	27	72	69	73	4.38	−1.0	15	3,922	ne.	34	w.	21	8	19	4	5.0	0.0	0.0
Augusta	182	62	77	29.76	29.95	−.07	84.7	+3.4	103	3	96	60	12	74	28	75	71	71	3.34	−2.0	13	3,103	s.	25	nw.	19	8	21	2	4.9	0.0	0.0
Savannah	65	150	194	29.90	29.97	−.06	83.5	+2.0	101	7	93	70	14	74	23	75	73	77	3.81	−2.8	13	6,176	s.	35	s.	24	8	9	14	5.9	0.0	0.0
Jacksonville	43	209	245	29.95	30.00	−.03	83.8	+1.7	98	3	92	70	19	76	26	75	73	76	2.20	−4.5	13	6,375	sw.	34	sw.	19	8	18	5	5.3	0.0	0.0
Florida Peninsula							83.5	+1.6										78	4.36	−1.2										6.0		
Key West	22	10	64	29.05	29.97	−.06	83.6	+0.1	92	9	89	74	12	78	14	77	75	76	3.23	0.0	13	6,057	se.	25	se.	26	6	15	10	6.1	0.0	0.0
Miami	25	124	168	29.98	30.01	−.04	82.8	+1.8	91	7	88	73	3	78	16	76	74	75	2.63	−2.8	10	5,580	se.	31	se.	26	3	15	13	6.8	0.0	0.0
Tampa	35	86	197	29.96	30.00	−.04	84.0	+2.8	96	25	92	71	2	76	23	76	75	82	7.23	−0.7	15	5,742	se.	32	sw.	5	3	20	8	6.1	0.0	0.0
Titusville	44	5	----	29.96	30.01	------	84.0	------	98	7	94	70	2	74	25	----	----	----	5.38	------	10	------	se.	----	------	----	11	13	7	5.1	0.0	0.0
East Gulf States							82.0	+1.4										77	7.30	+1.5										6.0		
Atlanta	1,173	190	216	28.78	29.98	−.04	81.0	+2.9	96	3	90	68	24	72	23	71	68	73	5.34	+0.7	11	4,961	w.	26	sw.	23	5	16	10	6.2	0.0	0.0
Macon	370	78	87	29.59	29.97	−.05	83.2	+2.0	102	3	93	68	9	73	27	74	70	70	6.49	+1.8	11	3,216	sw.	23	nw.	19	6	15	10	5.0	0.0	0.0
Thomasville	273	49	103	29.70	29.98	−.05	83.0	+1.2	100	2	93	69	23	73	25	75	73	82	6.55	−0.2	15	3,988	sw.	30	sw.	3	2	18	11	6.3	0.0	0.0
Apalachicola	36	11	51	29.95	29.99	------	82.6	------	94	3	89	71	23	76	17	77	75	78	5.72	−2.0	13	4,753	w.	32	se.	12	11	13	7	4.9	0.0	0.0
Pensacola	56	149	185	29.92	29.98	−.03	80.6	−0.4	90	5	86	70	25	76	17	76	74	80	11.11	+4.3	14	7,338	w.	38	s.	16	4	16	11	6.1	0.0	0.0
Anniston	741	9	57	------	------	------	81.2	+3.3	07	18	92	65	11	70	31	----	----	----	5.10	------	10	2,126	w.	16	nw.	21	11	12	8	----	0.0	0.0
Birmingham	700	11	48	29.24	29.99	−.02	81.8	+1.6	101	9	92	67	24	71	29	72	70	78	3.96	−1.2	16	3,095	sw.	27	s.	12	7	13	11	5.9	0.0	0.0
Mobile	57	125	161	29.92	29.98	−.03	82.2	+0.8	96	31	90	70	22	74	24	75	74	83	17.99	+11.1	16	5,391	sw.	32	e.	10	5	15	11	6.4	0.0	0.0
Montgomery	223	100	112	29.74	29.98	−.04	82.9	+1.2	98	8	92	70	27	74	22	74	71	75	3.18	−1.7	8	3,685	w.	22	nw.	21	4	14	13	6.6	0.0	0.0
Corinth	469	6	----	------	------	------	81.7	------	101	12	92	61	11	71	35	----	----	----	4.01	------	16	------	s.	----	------	----	4	25	2	----	0.0	0.0
Meridian	375	87	95	29.58	29.97	−.05	80.6	+0.2	97	1	90	66	24	72	26	73	70	77	8.14	+3.2	16	3,277	sw.	28	nw.	21	5	12	14	6.5	0.0	0.0
Vicksburg	247	65	73	29.70	29.97	−.03	81.6	+0.3	96	11	90	68	23	73	26	74	72	79	4.08	−0.4	13	4,066	se.	31	ne.	23	8	11	12	5.3	0.0	0.0
New Orleans	53	76	84	29.91	29.96	−.04	84.2	+1.8	98	9	92	70	15	77	19	76	74	76	7.77	+1.4	12	3,952	sw.	28	se.	15	6	20	5	5.6	0.0	0.0
West Gulf States							83.2	+0.6										73	3.29	+0.2										4.0		
Shreveport	240	204	220	29.66	29.92	−.06	84.2	+1.0	101	2	94	70	9	74	26	74	70	71	1.66	−1.9	8	4,825	s.	36	n.	21	11	11	9	4.9	0.0	0.0
Bentonville	1,303	11	44	28.59	29.92	−.05	79.0	+0.5	98	4	90	55	6	68	36	----	----	----	4.77	------	9	2,612	s.	25	ne.	24	26	3	2	----	0.0	0.0
Fort Smith	457	79	94	29.44	29.90	−.07	83.3	+1.8	102	1	94	64	6	73	31	73	68	67	3.10	−0.3	9	3,864	e.	26	se.	8	10	14	7	5.0	0.0	0.0
Little Rock	357	136	153	29.57	29.94	−.05	81.7	+0.6	101	1	91	68	11	73	27	73	70	74	3.74	+0.2	17	4,500	sw.	34	ne.	24	6	9	16	6.3	0.0	0.0
Austin	605	136	148	29.29	29.92	------	84.0	0.0	100	11	93	68	15	74	27	74	70	70	2.74	+0.4	9	4,323	s.	39	nw.	15	14	8	9	4.6	0.0	0.0
Brownsville	57	83	100	29.83	29.00	------	83.8	+0.2	95	9	91	73	17	76	19	76	74	79	2.79	+0.8	9	5,626	se.	28	se.	22	11	17	3	4.6	0.0	0.0
Corpus Christi	20	11	78	29.90	29.02	−.05	83.4	+0.7	94	10	89	71	18	78	17	77	75	80	11.92	+10.4	10	6,278	se.	33	se.	18	10	14	7	5.2	0.0	0.0
Dallas	512	220	227	29.38	29.92	------	84.6	------	100	2	94	68	8	76	29	----	----	----	1.61	−1.2	4	6,475	s.	59	n.	8	13	13	5	3.9	0.0	0.0
Fort Worth	670	106	114	29.20	29.89	−.07	84.8	+1.2	102	8	95	67	8	75	35	72	67	63	0.44	−2.2	4	5,297	sw.	38	ne.	8	13	12	6	4.6	0.0	0.0
Galveston	54	106	114	29.90	29.06	−.02	84.2	+0.8	96	10	89	73	17	80	15	77	74	76	1.02	−2.7	8	6,634	s.	24	se.	29	15	11	5	3.9	0.0	0.0
Houston	138	292	314	29.70	29.93	------	84.2	+0.5	97	2	92	72	14	76	22	----	----	----	3.39	−0.6	10	6,143	s.	35	w.	15	14	14	3	4.3	0.0	0.0
Palestine	510	64	72	29.42	29.94	−.03	83.0	+0.8	102	8	93	67	13	73	34	74	71	74	5.39	+2.7	9	4,115	s.	26	ne.	8	12	13	6	4.4	0.0	0.0
Port Arthur	34	58	66	29.90	29.94	------	84.3	------	96	10	02	71	0	77	25	76	74	75	3.10	−3.8	14	4,724	s.	25	e.	28	10	14	7	4.7	0.0	0.0
San Antonio	693	242	301	29.20	29.00	−.05	82.6	−1.2	96	13	91	71	17	74	23	73	70	72	3.09	+0.9	9	6,491	s.	31	se.	11	15	11	5	4.4	0.0	0.0
Taylor	571	38	51	29.36	29.96	.00	83.6	+0.9	09	8	94	69	16	73	27	----	----	----	2.07	−0.2	7	4,558	s.	34	e.	2	19	8	4	3.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, July, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	°F. 79.4	°F. +3.1	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 68	In. 4.29	In. +0.5		Miles								0-10 4.5	In.	In.
Chattanooga	762	190	215	29.16	29.95	−0.07	80.9	+2.5	96	17	90	67	11	71	26	72	68	71	4.08	−0.2	10	4,337	sw.	36	nw.	19	5	17	9	6.0	0.0	0.0
Knoxville	995	102	111	28.94	29.97	−.05	81.0	+3.9	98	2	92	66	12	70	28	71	68	72	7.94	+3.6	12	3,293	sw.	29	sw.	21	11	14	6	4.7	0.0	0.0
Memphis	399	76	97	29.53	29.94	−.06	80.6	−0.1	100	1	89	67	23	72	28	73	70	74	4.37	+1.2	15	4,315	sw.	34	n.	2	6	14	11	5.9	0.0	0.0
Nashville	546	168	191	29.40	29.97	−.04	81.6	+2.5	97	12	91	64	11	72	30	72	68	70	2.47	−1.4	10	4,080	w.	27	e.	8	6	16	9	5.3	0.0	0.0
Lexington	989	193	230	28.94	29.98	−.03	79.4	+3.5	96	17	89	63	11	70	24	----	----	----	8.50	+4.8	11	6,322	s.	40	w.	5	15	13	3	3.4	0.0	0.0
Louisville	525	188	234	29.39	29.96	−.04	81.2	+2.6	97	14	91	62	12	72	29	70	66	65	1.73	−2.0	10	5,091	sw.	43	nw.	19	16	11	4	4.2	0.0	0.0
Evansville	431	76	116	29.48	29.94	−.06	82.1	+3.4	99	2	92	64	11	72	30	71	65	61	0.73	−2.7	4	4,499	sw.	22	w.	22	17	9	5	4.0	0.0	0.0
Indianapolis	822	194	230	29.07	29.94	−.05	79.7	+4.0	98	2	89	60	11	70	25	67	61	58	2.95	−0.4	9	5,470	sw.	35	se.	18	17	11	3	3.6	0.0	0.0
Royal Center	736	11	55	29.17	29.94	------	76.4	------	98	16	88	51	11	65	30	----	----	----	2.62	−1.2	9	4,375	sw.	35	n.	21	17	10	4	4.0	0.0	0.0
Terre Haute	575	96	129	29.33	29.93	------	80.4	------	101	2	91	60	11	70	27	69	64	62	3.38	+0.2	6	4,403	sw.	24	n.	3	18	8	5	3.5	0.0	0.0
Cincinnati	627	11	51	29.29	29.95	−.05	79.2	+4.1	99	16	90	56	12	68	32	69	65	67	5.22	+1.9	11	3,231	sw.	30	sw.	22	18	10	3	3.5	0.0	0.0
Columbus	822	216	230	29.09	29.94	−.06	78.6	+3.7	98	16	89	61	11	68	26	68	63	64	4.66	+1.1	7	5,029	sw.	34	se.	31	8	19	4	4.6	0.0	0.0
Dayton	899	137	173	29.01	29.93	------	78.9	+3.5	98	16	90	57	12	68	31	68	63	63	6.74	+3.4	9	4,179	sw.	28	sw.	22	11	18	2	4.4	0.0	0.0
Elkins	1,947	59	67	28.00	29.97	−.04	73.0	+2.7	93	2	85	50	12	61	37	66	64	81	5.27	−0.1	13	2,388	nw.	28	nw.	20	9	14	8	5.0	0.0	0.0
Parkersburg	637	77	82	29.32	29.97	−.04	79.6	+4.2	99	1	90	57	12	69	30	69	65	68	2.62	−1.7	8	2,877	se.	23	w.	2	13	8	10	5.1	0.0	0.0
Pittsburgh	842	353	410	29.06	29.94	−.06	77.0	+2.4	97	2	87	57	12	67	29	68	64	69	5.36	+1.3	12	4,826	n.	45	n.	16	8	13	10	5.5	0.0	0.0
Lower Lake Region							75.4	+4.0										68	2.89	−0.4										5.1		
Buffalo	767	247	280	29.09	29.90	−.07	72.3	+2.5	91	2	78	57	10	66	23	66	63	74	3.24	+0.2	11	7,934	sw.	52	nw.	2	10	10	11	5.5	0.0	0.0
Canton	448	10	61	29.41	29.87	------	72.0	+1.5	98	1	82	54	25	62	28	----	----	----	4.91	+1.4	13	4,696	sw.	26	sw.	29	4	18	9	6.0	0.0	0.0
Ithaca	836	74	100	29.03	29.90	------	74.6	+4.1	102	2	85	54	26	64	34	67	63	71	2.73	−0.8	13	4,336	nw.	29	se.	5	6	15	10	6.3	0.0	0.0
Oswego	335	71	85	29.54	29.90	−.06	73.0	+2.6	93	2	80	59	25	66	25	67	63	73	2.49	−0.4	11	4,373	s.	21	n.	31	4	14	13	6.3	0.0	0.0
Rochester	523	86	102	29.36	29.92	−.05	74.8	+4.1	99	2	83	58	12	66	28	66	62	67	2.63	−0.3	11	4,314	sw.	28	w.	29	8	16	7	5.5	0.0	0.0
Syracuse	596	65	79	29.29	29.92	−.05	75.4	+4.6	100	2	84	60	12	66	26	----	----	----	3.81	+0.1	14	3,651	s.	21	sw.	29	6	15	10	5.9	0.0	0.0
Erie	714	130	166	29.17	29.92	−.06	75.0	+4.0	92	2	82	56	10	67	26	70	68	79	5.75	+2.7	14	6,454	sw.	36	nw.	10	15	8	8	4.2	0.0	0.0
Cleveland	762	267	337	29.12	29.92	−.07	76.3	+5.9	96	17	83	61	11	69	23	67	61	61	2.17	−1.3	10	6,473	n.	50	sw.	19	12	14	5	4.7	0.0	0.0
Sandusky	629	5	67	29.27	29.94	−.05	78.0	+4.6	99	17	88	58	11	68	30	----	----	----	1.03	−2.4	9	4,254	sw.	19	s.	5	9	16	6	4.9	0.0	0.0
Toledo	628	208	243	29.27	29.93	−.06	77.8	+4.6	99	17	87	61	24	68	26	67	61	60	1.24	−1.8	6	6,993	sw.	38	sw.	19	16	13	2	3.5	0.0	0.0
Fort Wayne	856	100	119	29.03	29.94	------	77.6	+4.1	99	17	88	55	11	67	27	67	62	62	2.56	−1.0	6	4,672	sw.	31	e.	1	15	12	4	3.8	0.0	0.0
Detroit	730	218	258	29.16	29.93	−.05	77.6	+5.5	100	17	87	60	10	68	27	67	62	64	1.81	−1.5	6	5,348	sw.	26	sw.	19	9	21	1	4.2	0.0	0.0
Upper Lake Region							72.0	+4.2										68	2.48	−0.6										4.4		
Alpena	609	13	92	29.26	29.92	−.05	70.2	+4.3	98	28	81	50	25	60	34	64	60	70	1.78	−1.0	10	6,498	nw.	40	nw.	16	11	13	7	4.5	0.0	0.0
Escanaba	612	54	60	29.25	29.90	−.07	69.6	+3.6	95	26	78	50	11	61	26	62	58	69	3.42	+0.1	11	5,731	s.	37	n.	19	12	13	6	4.3	0.0	0.0
Grand Haven	632	54	89	29.25	29.92	−.06	72.4	+3.7	92	16	81	51	12	64	29	65	61	66	2.63	0.0	7	6,050	sw.	30	nw.	17	15	9	7	4.3	0.0	0.0
Grand Rapids	707	70	244	29.18	29.92	−.06	75.8	+3.5	101	1	86	54	11	65	33	65	58	56	2.58	−0.3	5	6,577	sw.	33	sw.	5	14	9	8	4.8	0.0	0.0
Houghton	668	64	99	29.16	29.87	−.09	68.8	+3.3	95	1	78	50	10	60	34	----	----	----	1.52	−1.6	10	6,663	w.	30	e.	15	11	12	8	5.2	0.0	0.0
Lansing	878	6	88	29.00	29.92	------	73.8	+2.9	96	17	85	52	12	62	33	66	62	68	0.92	−2.2	7	4,301	sw.	18	w.	5	14	11	6	4.3	0.0	0.0
Ludington	637	60	66	29.24	29.92	------	70.9	+4.7	89	1	78	50	10	63	23	67	63	75	0.41	−2.6	6	5,854	s.	27	s.	5	20	7	4	2.8	0.0	0.0
Marquette	734	77	111	29.10	29.89	−.07	69.8	+4.9	100	1	79	51	11	61	29	62	57	68	4.65	+1.5	11	6,205	w.	37	sw.	27	9	13	9	5.4	0.0	0.0
Port Huron	638	70	120	29.23	29.92	−.06	73.9	+5.1	97	1	83	54	11	65	32	66	62	69	3.58	+0.8	11	5,693	s.	38	w.	17	12	11	8	4.7	0.0	0.0
Sault Sainte Marie	614	11	52	29.22	29.90	−.07	67.8	+4.0	97	1	77	47	10	58	32	62	58	73	2.33	−0.6	7	4,534	nw.	26	s.	19	15	12	4	4.2	0.0	0.0
Chicago	673	7	131	29.22	29.94	−.04	76.4	+3.9	99	1	84	60	6	69	24	67	63	67	2.68	−0.6	10	5,612	ne.	22	w.	17	17	11	3	3.5	0.0	0.0
Green Bay	617	109	141	29.25	29.90	−.07	75.0	+5.0	100	16	85	54	11	65	31	64	59	62	3.31	−0.2	10	6,188	sw.	35	w.	8	10	13	8	5.1	0.0	0.0
Milwaukee	681	125	221	29.20	29.92	−.05	75.5	+5.4	99	1	84	58	11	67	29	66	61	64	2.25	−0.6	7	7,871	w.	39	nw.	17	19	9	3	3.3	0.0	0.0
Duluth	1,133	5	47	28.71	29.90	−.05	68.5	+4.6	94	28	79	48	5	58	32	60	56	70	2.73	−1.0	10	7,376	nw.	36	w.	19	13	13	5	4.6	0.0	0.0
North Dakota							71.1	+2.6										60	3.09	+0.4										4.2		
Moorhead	940	50	58	28.87	29.86	−.08	72.5	+4.4	105	25	85	50	8	60	37	62	56	62	5.19	+1.8	14	5,314	s.	25	s.	14	10	14	7	4.9	0.0	0.0
Bismarck	1,674	8	57	28.12	29.86	−.07	71.6	+1.8	107	27	84	47	5	59	40	60	53	60	3.39	+1.2	11	5,959	nw.	32	sw.	18	18	8	5	3.5	0.0	0.0
Devils Lake	1,478	11	44	28.32	29.86	−.07	69.3	+1.9	105	25	82	46	5	57	41	60	54	65	3.01	+0.4	7	5,692	nw.	24	n.	18	13	10	8	4.8	0.0	0.0
Ellendale	1,457	10	56	28.35	29.89	------	72.4	------	108	25	87	46	5	58	47	----	----	----	2.03	−1.1	9	8,637	nw.	40	n.	27	13	14	4	4.3	0.0	0.0
Grand Forks	833	12	67	------	------	------	71.0	------	103	25	84	47	8	58	41	61	----	----	2.38	------	8	------	nw.	50	sw.	19	19	8	4	----	0.0	0.0
Williston	1,878	41	48	27.93	29.86	−.06	71.0	+2.1	105	25	84	46	1	58	40	58	49	52	1.83	−0.1	11	5,512	nw.	30	w.	6	19	8	4	3.4	0.0	0.0
Upper Mississippi Valley							78.8	+3.8										60	2.47	−1.1										3.7		
Minneapolis	918	102	208	28.92	29.88	------	76.8	+4.5	104	27	87	57	9	67	28	----	----	----	1.12	−2.6	8	7,063	s.	29	n.	28	11	12	8	4.6	0.0	0.0
St. Paul	837	114	149	29.00	29.88	−.07	76.2	+4.1	102	27	88	52	9	64	33	----	----	----	1.54	−2.0	8	5,726	sw.	30	nw.	8	14	10	7	3.8	0.0	0.0
La Crosse	714	11	48	29.14	29.89	−.07	76.6	+3.8	101	16	89	52	11	64	37	65	60	61	1.84	−2.1	6	2,487	s.	15	nw.	19	16	12	3	3.6	0.0	0.0
Madison	974	70	78	28.90	29.91	−.06	75.8	+3.7	97	17	86	56	11	66	28	65	59	58	2.10	−1.8	8	4,692	sw.	22	w.	19	19	8	4	3.2	0.0	0.0
Wausau	1,247	4	62	28.62	29.92	------	72.6	------	98	27	85	46	10	60	37	----	----	----	2.11	−2.2	10	3,570	n.	24	nw.	9	18	8	5	3.6	0.0	0.0
Charles City	1,015	10	51	28.86	29.91	−.05	76.8	+4.5	99	31	90	51	10	63	39	65	58	55	1.15	−2.6	7	3,792	se.	20	w.	1	19	9	3	2.8	0.0	0.0
Davenport	606	71	79	29.27	29.91	−.06	80.2	+4.9	102	30	91	59	10	69	33	68	61	55	2.05	−1.3	6	5,033	sw.	28	sw.	1	14	14	3	3.9	0.0	0.0
Des Moines	861	5	99	29.02	29.90	−.06	78.6	+3.2	107	28	90	56	8	68	29	68	62	61	3.60	+0.1	8	5,292	s.	32	w.	1	15	9	7	4.1	0.0	0.0
Dubuque	700	81	96	29.18	29.90	−.07	78.1	+4.0	100	1	89	53	10	67	32	66	60	58	2.57	−1.4	9	3,430	s.	17	nw.	19	18	9	4	3.3	0.0	0.0
Keokuk	614	64	78	29.27	29.93	−.05	80.5	+3.6	104	29	91	59	10	70	28	69	64	60	1.71	−1.7	8	3,586	sw.	17	nw.	19	17	8	6	3.7	0.0	0.0
Cairo	358	87	93	29.56	29.93	−.07	80.9	+1.3	100	1	90	66	25	72	26	72	68	70	1.97	−1.1	11	3,824	s.	20	ne.	1	12	11	8	5.2	0.0	0.0
Peoria	609	11	45	29.28	29.94	−.04	79.2	+3.8	102	30	91	56	10	68	28	70	66	68	5.91	+2.3	6	2,724	sw.	15	n.	9	19	10	2	3.1	0.0	0.0
Springfield, Ill	636	5	191	29.26	29.92	−.06	81.2	+4.7	102	1	92	60	11	70	28	69	62	58	2.78	−0.1	3	6,511	sw.	38	n.	19	13	15	3	3.8	0.0	0.0
Hannibal	534	74	109	29.36	29.92	−.06	80.4	+3.6	101	29	91	58	6	70	29	----	----	----	2.63	−0.5	10	4,446	sw.	22	se.	22	16	10	5	3.9	0.0	0.0
St. Louis	568	265	303	29.34	29.92	−.07	82.2	+3.1	104	1	92	66	6	72	28	69	63	57	4.06	+1.1	8	6,358	s.	40	sw.	22	19	9	3	3.3	0.0	0.0
Missouri Valley							79.5	+3.6										54	2.40	−1.2										3.4		
Columbia, Mo	784	6	84	29.11	29.92	−.06	81.0	+4.1	102	29	92	57	6	70	30	----	----	----	2.53	−1.0	8	3,854	s.	23	w.	4	17	11	3	3.5	0.0	0.0
Kansas City	963	161	181	28.90	29.90	−.07	81.7	+3.6	102	28	92	62	5	72	28	69	62	57	3.24	−0.9	9	4,947	se.	39	sw.	4	18	10	3	3.3	0.0	0.0
St. Joseph	967	11	49	28.89	29.88	------	80.6	------	103	28	92	57	8	69	31	69	64	61	4.05	+0.4	8	4,388	sw.	40	w.	12	17	11	3	2.9	0.0	0.0
Springfield, Mo	1,324	98	104	28.58	29.95	−.03	79.3	+2.5	98	1	89	61	6	70	27	69	64	63	4.08	−0.1	10	5,225	s.	31	ne.	23	20	10	1	2.5	0.0	0.0
Iola	984	11	50	28.89	29.90	−.07	81.2	+3.0	101	28	93	55	6	69	36	----	----	----	1.16	−2.6	9	3,422	s.	21	nw.	4	14	13	4	4.0	0.0	0.0
Topeka	987	92	107	------	------	------	80.7	+2.9	103	28	92	60	5	70	31	----	----	----	3.41	−0.9	9	5,394	s.	34	nw.	22	17	9	5	3.2	0.0	0.0
Lincoln	1,189	11	81	28.65	29.87	−.08	79.4	+2.9	105	28	91	54	5	68	33	67	60	58	2.04	−1.8	6	5,830	s.	32	nw.	1	14	9	8	4.4	0.0	0.0
Omaha	1,105	115	122	28.74	29.89	−.06	80.4	+3.7	105	28	90	57	5	70	27	66	59	53	2.10	−1.4	6	4,134	s.	22	nw.	8	20	7	4	2.9	0.0	0.0
Valentine	2,598	47	54	27.25	29.90	−.03	76.3	+2.6	106	27	90	48	5	63	41	62	53	51	4.02	+1.0	8	6,825	s.	33	w.	8	18	9	4	3.6	0.0	0.0
Sioux City	1,135	94	164	28.69	29.86	−.09	78.4	+4.1	99	30	89	53	9	67	31	65	58	54	1.74	−1.8	5	7,626	s.	36	n.	11	16	9	6	4.0	0.0	0.0
Huron	1,306	59	74	28.51	29.87	−.07	77.2	+5.4	106	15	92	49	5	63	38	63	54	49	1.38	−1.8	7	6,762	s.	28	nw.	6	21	8	2	2.9	0.0	0.0
Pierre	1,572	70	75	28.21	29.83	−.10	79.6	+4.3	112	15	94	52	5	66	44	62	51	43	0.71	−2.0	8	7,117	se.	46	ne.	30	16	14	1	3.5	0.0	0.0
Yankton	1,233	49	57	28.60	29.88	−.06	78.8	+4.6	103	28	91	54	9	67	36	----	----	----	0.75	−2.6	4	4,819	s.	29	sw.	14	15	11	5	3.7	0.0	0.0

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TABLE 1.—*Climatological data for Weather Bureau stations, July, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							71.0	+3.2										47	1.40	−0.2										3.8		
Billings	3,140	5	----	----	----	----	71.6	----	107	21	91	38	4	53	58	----	----	----	0.58	----	6	----	nw.	----	----	----	13	11	7	----	0.0	0.0
Havre	2,505	11	44	27.33	29.92	+0.01	69.4	+1.1	103	21	83	43	4	56	45	55	43	50	3.25	+1.4	8	5,200	nw.	32	n.	27	18	7	6	3.6	0.0	0.0
Helena	4,124	89	113	25.81	29.90	−.03	69.6	+3.9	102	21	84	38	5	56	40	53	40	42	1.29	+0.2	6	5,358	sw.	30	n.	6	15	11	5	4.1	T.	0.0
Kalispell	2,973	48	56	26.92	29.91	−.02	67.2	+3.1	97	25	82	42	7	52	43	52	40	46	0.70	−0.4	7	4,176	nw.	35	sw.	9	16	7	8	4.0	0.0	0.0
Miles City	2,371	48	55	27.40	29.90	−.02	75.2	+2.3	107	23	89	48	8	62	43	59	48	47	0.77	−0.8	6	4,285	ne.	32	nw.	10	16	11	4	3.8	0.0	0.0
Rapid City	3,259	50	58	26.58	29.90	−.03	75.0	+4.0	105	25	88	46	7	62	41	59	48	46	1.42	−1.0	11	5,260	n.	40	nw.	5	15	14	2	3.6	0.0	0.0
Cheyenne	6,088	84	101	24.09	29.89	−.03	70.0	+3.3	95	25	84	40	6	56	40	54	43	46	0.75	----	8	6,936	w.	34	w.	3	12	13	6	4.2	0.0	0.0
Lander	5,372	60	68	24.68	29.87	−.05	71.7	+4.3	100	21	88	40	7	55	44	54	42	43	2.10	+1.4	8	3,415	sw.	31	sw.	10	20	9	2	2.8	0.0	0.0
Sheridan	3,790	10	47	26.09	29.90	----	71.6	----	103	27	89	40	7	54	54	56	46	51	1.43	+0.2	8	2,691	nw.	30	nw.	5	16	12	3	3.8	0.0	0.0
Yellowstone Park	6,241	11	48	23.97	29.94	+.02	63.6	+2.1	92	21	80	33	6	48	42	49	38	49	0.72	−0.6	9	4,873	sw.	30	n.	5	14	12	5	4.0	0.0	0.0
North Platte	2,821	11	51	27.03	29.87	−.06	77.6	+4.7	103	22	91	48	5	64	44	63	55	52	0.97	−1.8	8	4,478	se.	29	ne.	12	15	13	3	3.6	0.0	0.0
Middle Slope							79.8	+2.6										52	1.39	−1.4										3.4		
Denver	5,292	106	113	24.77	29.89	−.02	76.0	+3.8	100	22	89	49	6	63	37	57	45	40	0.90	−0.8	6	4,530	s.	26	nw.	16	12	17	2	4.0	0.0	0.0
Pueblo	4,685	80	86	25.31	29.86	−.05	77.2	+3.0	103	22	92	47	5	62	46	58	46	42	0.86	−1.1	8	4,153	e.	32	nw.	15	19	10	2	3.8	0.0	0.0
Concordia	1,392	50	58	28.47	29.89	−.06	81.1	+3.1	109	27	93	54	5	69	34	67	60	56	3.04	−0.7	4	4,815	s.	20	s.	11	19	9	3	3.1	0.0	0.0
Dodge City	2,509	88	100	27.38	29.90	−.03	79.6	+1.2	104	22	92	51	5	67	36	65	57	55	2.00	−1.1	10	8,106	s	34	sw.	31	22	7	2	2.6	0.0	0.0
Wichita	1,358	139	158	28.49	29.88	−.08	81.6	+2.2	101	27	92	60	5	71	31	68	62	57	0.97	−2.4	5	7,922	s.	36	n.	4	13	16	2	3.6	0.0	0.0
Oklahoma City	1,214	10	47	28.64	29.88	−.08	83.4	+2.8	104	4	95	61	6	72	36	70	64	59	0.55	−2.3	3	5,645	s.	23	nw.	8	18	9	4	3.5	0.0	0.0
Southern Slope							81.2	0.0										59	1.60	−0.8										3.6		
Abilene	1,738	10	52	28.13	29.88	−.05	83.6	+0.8	101	7	95	65	6	72	34	69	62	57	2.21	+0.1	6	5,746	s.	27	e.	8	14	13	4	4.2	0.0	0.0
Amarillo	3,676	10	49	26.27	29.90	−.02	79.4	+2.6	101	23	92	57	5	66	36	64	57	55	1.40	−1.4	9	5,805	s.	31	s.	12	20	9	2	2.9	0.0	0.0
Del Rio	944	64	71	28.88	29.84	−.06	82.7	−3.6	96	7	92	67	10	73	25	73	69	70	1.84	−0.6	5	5,482	se.	34	e.	10	11	16	4	4.5	0.0	0.0
Roswell	3,566	75	85	26.35	29.86	−.02	79.0	+0.1	99	6	92	59	6	66	40	64	56	54	0.98	−1.3	8	4,856	se.	25	se.	20	21	9	1	2.6	0.0	0.0
Southern Plateau							82.8	+3.9										47	0.39	−0.8										2.9		
El Paso	3,778	152	175	26.13	29.79	−.05	83.2	+2.1	102	16	94	65	6	72	32	65	55	44	0.73	−1.3	7	5,066	e.	34	ne.	17	19	11	1	3.0	0.0	0.0
Albuquerque	4,972	51	66	25.06	29.79	----	77.7	----	99	23	91	58	6	64	37	61	52	50	0.69	----	4	3,819	sw.	28	se.	20	14	13	4	4.1	0.0	0.0
Santa Fe	7,013	38	53	23.35	29.84	−.04	70.2	+1.2	90	22	82	48	5	58	31	55	46	50	1.00	−1.4	15	3,652	se.	20	n.	25	8	19	4	4.8	0.0	0.0
Flagstaff	6,907	10	59	23.43	29.81	−.02	68.6	+3.6	92	25	84	42	6	53	44	55	----	59	2.71	----	13	4,572	nw.	31	nw.	11	2	20	9	----	0.0	0.0
Phoenix	1,108	10	107	28.58	29.68	−.10	95.2	+5.4	114	24	108	77	31	83	30	71	59	35	0.02	−1.0	2	4,113	w.	34	e.	11	28	3	0	1.7	0.0	0.0
Yuma	141	9	54	29.55	29.69	−.07	95.0	+4.2	116	2	108	73	22	81	36	75	66	45	0.21	0.0	3	3,660	sw.	35	e.	21	28	3	0	1.1	0.0	0.0
Independence	3,957	6	27	25.89	29.82	−.01	84.7	+6.6	106	19	101	58	15	69	40	57	----	----	0.00	−0.1	0	----	nw.	----	----	----	21	4	6	----	0.0	0.0
Middle Plateau							78.5	+6.1										28	0.41	−0.1										2.2		
Reno	4,532	74	81	25.44	29.82	−.05	77.4	+9.9	106	20	95	50	1	60	43	54	36	28	T.	−0.2	0	4,589	w.	30	w.	15	26	5	0	1.4	0.0	0.0
Tonopah	6,090	12	20	----	----	----	78.6	----	98	19	92	52	4	66	36	55	37	25	0.10	----	1	----	nw.	----	----	----	----	----	----	----	0.0	0.0
Winnemucca	4,341	18	56	25.58	29.85	−.05	77.2	+6.6	108	20	96	42	1	58	53	53	33	24	0.12	−0.1	1	4,291	sw.	31	s.	24	23	8	0	1.6	0.0	0.0
Modena	5,473	10	43	24.62	29.79	−.07	76.3	+5.7	101	26	93	42	5	59	51	54	36	31	0.52	−0.6	3	6,800	w.	36	sw.	14	16	12	3	3.6	0.0	0.0
Salt Lake City	4,360	163	203	25.58	29.82	−.08	80.8	+5.1	105	24	93	55	5	68	36	57	39	26	0.61	+0.1	3	5,025	nw.	32	s.	29	25	4	2	1.7	0.0	0.0
Grand Junction	4,602	60	68	25.34	29.82	−.07	80.9	+3.2	104	23	96	55	3	66	39	57	41	32	0.74	+0.1	4	4,045	se.	37	s.	27	21	7	3	2.8	0.0	0.0
Northern Plateau							75.1	+4.1										33	0.12	−0.4										2.2		
Baker	3,471	48	53	26.43	29.93	−.02	70.0	+4.4	102	20	86	41	1	54	47	52	38	35	0.07	−0.5	1	3,743	n.	24	nw.	5	22	8	1	2.4	0.0	0.0
Boise	2,739	79	87	27.08	29.86	−.07	77.4	+4.5	108	20	94	47	6	61	43	56	41	32	T.	−0.2	0	3,057	nw.	22	n.	5	24	3	4	2.2	0.0	0.0
Lewiston	757	40	18	29.11	29.90	−.05	77.8	+3.8	114	20	95	49	1	61	53	----	----	----	0.02	−0.5	1	2,436	e.	21	nw.	10	22	7	2	2.5	0.0	0.0
Pocatello	4,477	60	68	25.46	29.84	−.08	75.8	+5.0	105	21	91	46	7	60	42	53	35	30	0.62	−0.2	4	4,876	se.	30	sw.	24	21	5	5	2.9	0.0	0.0
Spokane	1,929	101	110	27.91	29.91	−.05	72.8	+3.8	106	20	87	44	1	58	48	54	38	36	T.	−0.7	0	3,602	s.	21	sw.	10	22	7	2	2.1	0.0	0.0
Walla Walla	991	57	65	28.84	29.90	−.07	76.9	+2.9	105	20	92	49	1	62	40	57	39	31	0.11	−0.3	2	2,754	w.	14	w.	10	23	8	0	1.8	0.0	0.0
Yakima	1,076	58	67	28.79	29.92	----	75.9	+4.5	103	20	91	52	14	61	39	56	40	34	T.	−0.3	0	4,352	nw.	20	nw.	2	23	7	1	1.5	0.0	0.0
North Pacific Coast Region							64.1	+2.0										66	0.04	−0.6										3.4		
North Head	211	11	56	29.83	30.06	−.02	58.1	+0.9	85	7	62	47	19	54	31	55	53	85	0.09	−0.9	3	9,934	n.	34	n.	4	9	10	12	5.6	0.0	0.0
Port Angeles	29	8	53	----	30.06	----	60.4	----	86	6	69	44	27	52	32	----	----	----	0.14	−0.3	2	4,811	sw.	25	nw.	4	20	7	4	----	0.0	0.0
Seattle	125	215	250	29.88	30.01	−.03	65.2	+2.1	90	8	74	52	1	56	28	57	52	65	0.11	−0.5	3	4,593	ne.	28	sw.	20	19	7	5	3.1	0.0	0.0
Tacoma	194	172	201	29.83	30.03	−.03	64.8	+2.0	88	8	74	48	1	55	28	----	----	----	T.	−0.6	0	4,830	n.	30	sw.	20	16	11	4	3.6	0.0	0.0
Tatoosh Island	86	9	53	29.95	30.04	−.01	56.6	+1.5	76	7	61	47	31	52	24	54	53	90	0.30	−1.2	4	6,881	sw.	36	s.	20	6	11	14	6.4	0.0	0.0
Medford	1,329	29	58	28.51	29.88	----	74.3	----	105	19	93	48	3	56	48	57	44	44	0.00	−0.4	0	4,080	nw.	24	nw.	20	27	4	0	0.9	0.0	0.0
Portland, Oreg.	153	68	106	29.83	29.98	−.07	70.1	+3.4	101	19	82	53	27	58	36	59	52	58	T.	−0.6	0	4,236	nw.	18	nw.	5	20	7	4	3.0	0.0	0.0
Roseburg	510	75	99	29.42	29.96	−.07	69.6	+2.2	102	19	84	48	1	55	46	58	49	57	0.00	−0.3	0	3,281	n.	22	n.	3	25	6	0	1.5	0.0	0.0
Middle Pacific Coast Region							71.2	+4.2										58	T.	0.0										1.9		
Eureka	62	73	89	29.90	29.97	−.08	56.6	+1.1	76	4	61	48	27	52	24	53	51	85	0.01	−0.1	1	4,445	nw.	27	n.	2	13	13	5	4.3	0.0	0.0
Red Bluff	330	5	58	29.41	29.75	−.14	87.0	+6.2	114	19	104	59	16	70	45	62	43	27	0.00	0.0	0	3,671	s.	22	nw.	3	30	1	0	0.5	0.0	0.0
Sacramento	69	106	117	29.69	29.76	−.12	79.5	+6.3	109	4	98	52	16	61	47	62	50	46	T.	0.0	0	5,717	s.	18	sw.	14	30	1	0	0.6	0.0	0.0
San Francisco	155	208	243	29.68	29.84	−.11	62.3	+3.8	99	3	70	51	31	55	37	55	52	75	T.	0.0	0	5,470	sw.	25	nw.	14	18	12	1	2.8	0.0	0.0
San Jose	141	12	110	29.70	29.85	----	70.7	+3.8	106	3	85	50	16	56	46	----	----	----	0.00	0.0	0	3,815	nw.	18	nw.	1	27	3	1	1.3	0.0	0.0
South Pacific Coast Region							79.5	+6.3										59	T.	0.0										2.5		
Fresno	327	89	98	29.40	29.74	−.09	87.6	+5.5	113	26	105	60	16	71	39	62	42	26	T.	0.0	0	5,183	nw.	20	nw.	14	28	3	0	0.8	0.0	0.0
Los Angeles	338	159	191	29.46	29.81	−.09	77.2	+7.0	94	25	86	64	5	68	26	68	64	72	0.00	0.0	0	2,949	sw.	16	w.	25	25	5	1	2.4	0.0	0.0
San Diego	87	62	70	29.72	29.81	−.11	73.6	+6.4	85	26	78	62	1	69	18	68	66	80	T.	0.0	0	3,714	sw.	16	s.	9	11	17	3	4.4	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.88	29.96	----	81.5	+1.4	90	2	86	74	24	77	14	----	----	----	9.56	+3.6	20	6,992	e.	41	ne.	24	2	22	7	6.1	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	----	[1] 29.83	+.01	79.4	−0.9	87	15	84	72	14	74	15	----	----	[1] 88	10.46	+3.2	26	3,466	s.	20	sw.	20	0	9	22	8.2	0.0	0.0
Cristobal	30	6	97	----	[1] 29.82	−.02	81.6	+1.2	91	9	88	74	20	76	15	76	75	[1] 83	13.36	−2.3	25	4,125	se.	24	sw.	16	0	7	24	8.6	0.0	0.0
Alaska																																
Fairbanks	455	11	41	[2] 29.37	[2] 29.87		58.4	----	80	1	68	40	11	48	32	52	47	70	1.43	----	17	2,812	w.	20	sw.	5	3	9	19	7.4	0.0	0.0
Juneau	80	11	50	[2] 29.96	[2] 30.05	----	55.1	----	78	3	61	46	3	49	31	52	49	82	5.71	----	22	3,321	s.	23	se.	21	5	5	21	7.7	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.97	[2] 30.01	----	77.8	+0.1	84	1	82	70	7	73	12	70	67	70	0.52	−0.7	15	6,457	e.	24	ne.	21	18	11	2	3.5	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, late reports, June, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99												
Sydney, C. B. I	48	29.90	29.95	0.00	56.3	+0.9	65.7	46.9	78	40	4.32	+1.09	0.0
Halifax, N. S	88	29.81	29.91	−.04	59.1	+1.4	68.1	50.2	88	44	6.30	+2.54	0.0
Yarmouth, N. S	65	29.79	29.86	−.09	58.0	+3.0	65.3	50.8	75	42	5.74	+2.81	0.0
Charlottetown, P. E. I	38	29.83	29.87	−.05	56.5	−0.9	64.0	49.1	81	42	3.32	+0.65	0.0
Chatham, N. B	28	29.83	29.86	−.03	57.8	−2.2	67.6	48.1	86	39	4.53	+1.07	0.0
Father Point, Que	20												
Quebec, Que	296	29.63	29.95	+.03	62.3	+1.1	72.0	52.6	86	45	7.72	+4.07	0.0
Doucet, Que	1,236				54.8		72.2	37.5	94	25	2.56		0.0
Montreal, Que	187	29.73	29.93	−.01	66.7	+1.8	75.9	57.5	89	49	3.81	+0.28	0.0
Ottawa, Ont	236	29.70	29.96	+.02	65.5	+0.2	76.5	54.5	94	44	1.75	−1.17	0.0
Kingston, Ont	285	29.67	29.98	+.01	63.9	+0.5	71.5	56.3	81	49	2.61	+0.18	0.0
Toronto, Ont	379	29.58	29.97	.00	65.9	+2.5	75.7	56.1	91	43	2.16	−0.64	0.0
Cochrane, Ont	930												
White River, Ont	1,244	28.64	29.93	−.01	60.2	+1.5	74.9	45.5	101	25	0.79	−1.43	0.0
London, Ont	808				65.1		77.1	53.1	96	38	3.14		0.0
Southampton, Ont	656	29.29	30.00	+.03	61.5	+1.1	72.0	51.0	90	35	1.83	−0.52	0.0
Parry Sound, Ont	688	29.31	29.99	+.03	62.9	+1.2	73.1	52.8	90	39	1.80	−0.62	0.0
Port Arthur, Ont	644	29.25	29.96	+.02	58.3	+1.9	67.5	49.1	90	37	2.34	−0.39	0.0
Winnipeg, Man	760	29.06	29.87	−.02	65.8	+3.6	77.4	54.3	97	34	1.13	−2.16	0.0
Minnedosa, Man	1,690	28.09	29.87	−.02	63.5	+3.9	77.6	49.5	108	27	1.78	−1.22	0.0
Le Pas, Man	860				59.4		70.5	48.4	92	37	1.48		0.0
Qu'Appelle, Sask	2,115	27.62	29.82	−.05	63.7	+3.8	77.9	49.4	100	31	1.54	−1.88	0.0
Moose Jaw, Sask	1,759				65.9		80.1	51.6	99	39	3.95		0.0
Swift Current, Sask	2,392	27.31	29.77	−.10	65.8	+5.8	80.8	50.9	102	36	2.45	−0.22	0.0
Medicine Hat, Alb	2,365	27.36	29.79	−.06	64.9	+2.9	78.2	51.6	94	36	2.13	−0.63	0.0
Calgary, Alb	3,428	26.25	29.87	+.03	57.2	+1.2	69.0	45.5	84	37	2.17	−0.28	0.0
Banff, Alb	4,521	25.32	29.82	−.02	52.4	+0.9	63.9	40.9	80	29	3.64	+0.31	0.0
Prince Albert, Sask	1,450	28.32	29.86	−.01	60.7	+3.0	72.6	48.9	96	35	2.83	+0.32	0.0
Battleford, Sask	1,592	28.10	29.81	−.05	60.9	+1.4	74.7	47.1	92	31	0.89	−2.42	0.0
Edmonton, Alb	2,150	27.54	29.78	−.06	57.4	+0.5	68.7	46.2	86	30	5.97	+3.11	0.0
Kamloops, B. C	1,262	28.59	29.86	−.01	63.2	−0.6	72.8	53.7	92	46	1.25	−0.17	0.0
Victoria, B. C	230	29.73	29.98	−.03	56.7	+0.4	63.3	50.2	80	47	4.33	+3.13	0.0
Estevan Point, B. C	20				52.4		59.2	45.7	72	40	7.05		0.0
Prince Rupert, B. C	170				54.3		61.9	46.8	74	40	1.77		0.0
Hamilton, Ber	151												

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CLOSED OCTOBER 3, 1931
ISSUED NOVEMBER 5, 1931

SOME PROBLEMS OF THE BOULDER CANYON-COLORADO RIVER DEVELOPMENT

By JOHN L. BACON, Chairman, California-Colorado River Commission

June 15, 1931.

The Colorado River, like all streams flowing through a semiarid country, has periods of extreme high and low flow. These periods are of annual occurrence and are fairly uniform both as to amount and time. During the periods of high water a serious flood condition exists along the lower reaches of the river that at times is an acute menace. During the low-water periods there is sometimes an absolute water shortage, with not enough water to supply the existing demand for irrigation and domestic purposes. This low-water flow naturally limits the demand that may be satisfied from the river, and the limit has been reached.

The variation in the flow of the Colorado is very great. Many seasons the flood has reached a flow in excess of 200,000 cubic feet per second, and during the dry season this flow has dropped below 2,000 second-feet. About 5,000 or 6,000 second-feet of flow is required to satisfy the demand at and below Yuma.

One condition exists that is peculiar to this river—the largest single area using water lies entirely below sea level. The Imperial Irrigation District, comprising over half a million acres, lies in what at one time was the end of the Gulf of California. Silt brought down by the Colorado formed a delta across this arm of the sea, extending across the entire width of the valley, from the present bank of the river in Arizona to the high hills along the western side of the valley in California. Silt formed the valley and now threatens to destroy it by the continual building up of the delta and the forcing of the river into new channels that have a constantly increasing tendency to flow back into the valley below.

The amount of silt coming down the river every year is about equal to the total amount of excavation the Americans dug out of the Panama Canal. To prevent the mouth of the river being diverted down the northern slope of the delta and back into the Imperial Valley by the ever-increasing deposit of silt, the Imperial Irrigation District has been compelled to maintain an ever-lengthening system of dikes or levees along the lower reaches of the river in Mexico. To-day there are about 75 miles of these levees in use, and some 21 miles in addition have been built, which have either been destroyed by the river or abandoned on account of improper location.

The elevation of the delta, where the river is flowing, is some 50 to 75 feet above sea level, while the Salton Sea, which fills the bottom of the bowl forming the Imperial Valley, has a surface elevation of about 250 feet below sea level.

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In addition to the natural difficulties encountered on the Colorado there are many and grave political complications. The Colorado flows through the States of Arizona, Nevada, New Mexico, Utah, Colorado, and Wyoming and borders on California for some 250 miles. From the international border line the river flows through Mexico before entering the Gulf of California, and considerable water is used there for irrigation. There are vast areas in each of these States, as well as Mexico, whose every interest is entirely dependent upon the water obtained from the Colorado. Each of these areas is jealous of development in other areas and will go to almost any length to protect real or fancied opportunities of future development.

We have, then, not only an interstate but an international complication. We have no treaty with Mexico regarding allocation or use of Colorado River water. There is no agreement between the States making a definite allocation of use between individual States, although the so-called Colorado River compact does make an allocation of use between two groups of States known as the upper and lower basin States. Roughly, the States of Arizona, California, and Nevada comprise the lower basin and the States of Utah, Colorado, Wyoming, and New Mexico the upper basin, although portions of some of the States overlap both basins.

Problems on the Colorado were really brought to an acute head by conditions in the Imperial Valley. When irrigation and settlement first started in 1902 little attention was paid to the delta conditions and water was diverted through an old stream bed running along close to the top of the delta, starting at about the intersection of the Colorado with the international boundary line, looping down through Mexico, and crossing back into the United States about 40 miles west of the Colorado.

The promoters had a concession from the Mexican Government under the terms of which Mexican lands were to have half of the water flowing in the canal at any time.

Some 13 years ago the people of Imperial Valley, realizing that serious conditions were developing and that the problems were becoming too serious for them to handle, went to Congress and asked for aid. The first step was a bill to construct what was known as an All-American Canal to connect the Colorado River with the Imperial Valley and relieve the valley of the ever-increasing international complications that were developing. This bill was not passed, but it did, along with other bills which succeeded it, rouse sufficient interest so that Con-

gress in 1920 authorized a thorough investigation and report of the conditions on the Colorado with the view of determining some possible solution of the ever-increasing difficulties.

The result of the above investigation was a report rendered in 1920, known as the Fall-Davis report, recommending the construction of the Boulder Dam, afterward named the Hoover Dam. As set forth in the report, the object of such a dam was to provide sufficient storage to impound an entire year's run-off of the Colorado, and then feed this stored water downstream for use when needed, thus utilizing the flood waters that had been running to waste and making them available when most needed during the dry periods. It also recommended that the waters from the dam be passed through a power house and that the energy thus generated be sold, it being believed that the income from this source would be sufficient to repay the entire cost of the investment. An all-American canal was also recommended to carry water from the river to the Imperial Valley and replace the present canal in Mexico.

This was the solution offered by the Government engineers, and so well was it worked out that, though numerous other investigations have since been made and many other reports rendered, the development as it is going ahead to-day practically follows the recommendations made in the Fall-Davis report.

Briefly, the situation might be summed up in this way: The conditions were laid before the Reclamation Department and after careful investigation the answer came back—build Boulder Dam. The object to be attained was to control the river, store the floods, and feed down the water when needed, and in the process of feeding down the water run it through a power house and let the drop of the water pay for the cost of control by selling the power thus generated.

After numerous failures to obtain favorable action by Congress, the so-called Swing-Johnson bill was passed, authorizing the construction of a dam in the Colorado River at Black or Boulder Canyon, the construction of a power plant below the dam, and the building of the All-American Canal. This bill passed December, 1928, and the first appropriation was authorized in the deficiency appropriation bill signed by President Hoover July 3, 1930.

These are only a few of the high points among the events leading up to the start of the Hoover Dam.

The financing of the project and the actual construction present many interesting and big problems. Before work could start the Secretary of the Interior was compelled by the terms of the act to have contracts for the disposal of the power that would guarantee to the Government the full repayment of all money invested plus interest at 4 per cent. This was accomplished. An immense river must be diverted from its bed and carried around the actual site of the dam. The structure will be the largest block of concrete ever cast, The mere financing of the construction work by the contractors is no mean proposition.

The Boulder Dam, as it has been popularly known, or the Hoover Dam, as it is now and will hereafter be officially known, is to be an arch gravity section concrete dam in the Colorado River about 250 miles upstream from the point where the Colorado crosses the international boundary line between California and Mexico. The location is about 150 miles below the limits of the Grand Canyon National Park. These distances are measured along the river and would be slightly shorter if taken in a direct line. It is about 30 miles southeast of Las Vegas, Nevada, the nearest city. The river at this point runs through a deep, narrow gorge over 1,000 feet deep, that almost looks as though nature had provided it for this particular purpose.

The dam will be over 700 feet high from bedrock to top, will impound over 30,000,000 acre-feet of water, creating the largest artificial body of water in existence behind one dam, and will make an artificial lake over 100 miles long.

The financing of the project has proven an extremely interesting problem. The act provided for considerable latitude. The Government could either lease the right to use the falling water, it could build a power plant and lease the plant or units of the plant, or it could build and operate the plant and sell the power thus generated at the switchboard.

A sort of combination of these methods was finally worked out, and under the final contracts the Government is to build the building housing the power plant and control the water up to the control valves, the lessees pay for the generating machinery and operate it, and pay the Government for the use of the falling water, the rate of payment to be governed and measured by the amount of water required to generate a kilowatt of electrical energy at the switchboard at the plant. The rate to be paid is 1.63 mills per kilowatt-hour for primary or firm power and 0.5 mill for secondary or what might be termed "spill" power. There will be other items of income, but the income from power alone during the 50-year amortization period of the dam will yield an average of over $7,000,000 per year. Of this income Arizona and Nevada will *each* receive over $600,000 annually, without the expenditure of anything on their part.

During the 50 years in which the dam and all expenditures must be paid for, with interest at 4 per cent, the income will be sufficient to pay all capital costs, operate and maintain the works, provide for depreciation, pay the interest, pay the amounts given above to Nevada and Arizona, and in addition provide a fund that may be used for general development of the Colorado of over $66,500,000. The initial cost to the Government, including $11,554,000 to be charged for interest during construction period, is estimated at $121,000,000. In addition the All-American Canal, estimated to cost about $32,000,000, will be a separate financial set-up.

Perhaps the most novel feature of the construction of this huge dam is the method to be used to carry off the heat generated by the chemical combinations and reactions of the setting cement. Very little attention is ordinarily paid to this in common practice, as the mass of the setting concrete is generally small enough to permit the radiation of the heat generated without any difficulty; but in the case of the Hoover Dam, where the mass is over 600 feet thick in some places, the carrying off of this heat becomes a real problem. A method or refrigeration, or artificial cooling, has been worked out to take care of the unusual conditions brought about by the great mass of the concrete and by the rapidity of pouring. (It is expected to pour concrete at the rate of 3,000 yards per day.) Shrinkage takes place in the mass until the heat generated by setting has been dissipated.

The following data have been furnished by the Denver office of the Reclamation Department:

The object to be obtained by artificially cooling the concrete during the setting period is to dissipate its setting heat in a rela-

tively short period of time, so that the resultant shrinkage of the mass will take place before it is necessary to pressure grout the construction joints and impound water behind the dam. The chemical action in setting concrete develops a large amount of heat, which heat is rapidly dissipated by radiation when in masses of small dimensions. On the other hand, this heat radiation from large masses is relatively very slow and varies as the square of the dimensions of the mass. On this basis the degree of cooling that would naturally take place by radiation from a mass 50 feet in thickness (a representative dimension for concrete arch dams of ordinary magnitude) in one years' time would require a century if the structure were 500 feet thick, which may be taken as the average thickness of the Hoover Dam. Shrinkage in the mass will continue until the setting heat is dissipated. To correct for this and to make the structure monolithic and water-tight, the contraction joints provided for this purpose will be filled with cement grout under pressure after the cement has cooled. The artificial cooling is therefore required in order to permit the completion and use of the dam within a permissible period of time. The rated capacity of the cooling plant is 600 tons per day.

The circulating pipes in the concrete are to be spaced 10 feet apart vertically and about 11½ feet apart horizontally. The approximate basis for estimating the amount of heat to be removed is 50,000 to 60,000 B. t. u. per cubic yard of concrete as an average condition. Data of record relative to the thermal properties of concrete are comparatively meager and, in some instances, apparently erroneous. A suitable series of experiments will be conducted to establish these properties for the specific materials to be used before concrete placing is begun.

The injurious effects to be anticipated if no provision were made for artificial cooling are the cracking of the concrete and the opening up of the construction joints due to shrinkage from cooling after the structure is completed and put in use. Such cracks and open construction joints would invite leakage and would disarrange the distribution of stresses between the arch and cantilever elements, which would result in concentrated stresses much higher than calculated in the design of the dam due to the structure not being able to act as a monolith.

The turning of the river to permit the unwatering of the actual dam site is no mean undertaking. To do this, four tunnels are to be driven, two on the Nevada side and two on the Arizona side of the river. The bottom elevation of these tunnels will be about the low-water flow line of the river. Each tunnel will be about 50 feet in diameter when finished, and the combined capacities of all four will be about sufficient to take care of the average flow of the Mississippi River at St. Louis. The capacity will be 200,000 cubic feet of water per second. When these tunnels are completed, cofferdams of rock-fill construction, faced upstream with steel-pile cut-off walls, will be constructed, one just below the upstream intakes and one just above the downstream discharge ends of the tunnels. These cut-off dams will raise the water at the upstream end and divert the flow of the river through the completed tunnels, and the downstream dam will prevent the water from backing up and flooding the site.

After the main dam is completed, all four of the tunnels will be plugged at the upstream ends. One tunnel on each side of the river will be used for a spillway by connecting with a slanting shaft having its upper end at the water surface of filled reservoir. The other two tunnels will be plugged at both ends and will be utilized as pressure tunnels to connect with the control gates in the inlet towers.

SOME FIGURES ON THE HOOVER DAM

In order to gain some conception of the magnitude of this great project it does not seem out of place to list some of the items that will enter into it.

Tunnels.—Combined length, 3.1 miles; cubic yards of excavation in rock, 1,900,000.

Cofferdams.—1,200,000 cubic yards of rock and earth fill.

Reinforcing steel bars and rails.—35,500,000 pounds.

Concrete.—4,400,000 cubic yards.

Miscellaneous items.—Small metal pipe and fittings, 1,900,000 pounds; structural steel, 10,600,000 pounds; large metal conduits, 32,500,000 pounds; metal work, gates, hoists, etc., 20,000,000 pounds.

Time to build.—About six or seven years.

It is estimated that it will require about 350 carloads of material daily to keep up with the demand for supplies during the construction period.

Even the seemingly simple element of elevator service looms rather large when it is realized that enough workmen to man a good-sized manufacturing plant must be handled in and out of a canyon over a thousand feet deep.

This dam will be the Government's answer to a series of vexing problems that have developed in connection with the river and will, as has been aptly said, "Convert a natural menace into a national resource" and will mark one more milepost in man's struggle against nature.

SOUNDING-BALLOON OBSERVATIONS MADE AT BROKEN ARROW, OKLA., DURING THE INTERNATIONAL MONTH, DECEMBER, 1929

By L. T. Samuels

[Weather Bureau, Washington, D. C., July, 1931]

In cooperation with the International Commission for the Exploration of the Upper Atmosphere the Weather Bureau conducted a series of sounding-balloon observations at the Broken Arrow [1] (Okla.) aerological station during the international month, December, 1929. The instruments used were of the Fergusson type. The balloons were made of seamless rubber and weighed between 575 and 1,238 grams. They were spherical in shape, between 75 and 100 centimeters diameter, and were inflated to between 137 and 158 centimeters diameter. This gave a free lift of approximately 500 grams and an ascensional rate of about 238 meters per minute.

The balloons were released daily about one hour before sunset so as to eliminate, so far as possible, the effects of insolation on the meteorograph and still make possible the use of theodolites to follow the balloons. On the 17th, 18th, and 19th (international days) additional balloons were released shortly after sunrise. There were 34 observations made, and 26 (76 per cent) of the instruments were returned. One of the latter had the record sheet removed and another had a faulty pressure record. Of the eight instruments not returned, three were followed with two theodolites to the following heights, viz, 13,175 meters on the 2d, 7,420 meters on the 26th, and 17,590 meters on the 30th. Wind velocities and directions were determined to those elevations.

The balloons were followed with two theodolites whenever possible, and in nine cases these continued for 60 minutes or more, the longest run being 90 minutes on the 25th.

[1] Latitude 36° 02′ N., longitude 95° 49′ W.

The altitudes as determined from 2-theodolite observations and those obtained hypsometrically were in close agreement in most cases. The differences averaged less then 5 per cent. At levels below 10,000 meters the altitudes obtained hypsometrically averaged slightly less than those determined from the 2-theodolite readings and slightly greater at altitudes above 10,000 meters.

The 2-theodolite altitudes were corrected for the curvature of the earth's surface, which correction is additive and amounts to approximately 100 meters when the horizontal distance of the balloon is 35,000 meters and to 1,000 meters when this distance is around 113,000 meters. In some cases the balloon was observed to a horizontal distance of 120,000 meters, the curvature correction for that distance being 1,130 meters.

It will be noted from Figure 1 that practically all of the instruments landed within 200 kilometers of the station and none was found to the westward. The maximum distance from which an instrument was returned was 450

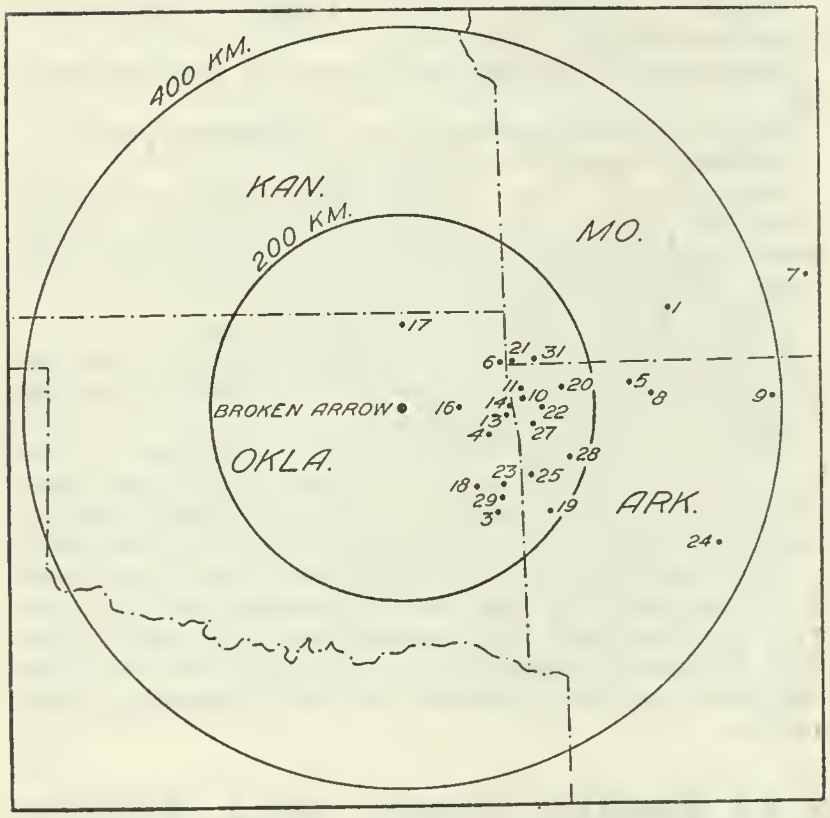


FIGURE 1.—Landing places (with dates) of meteorographs released from Broken Arrow, Okla., during December, 1929

kilometers. This one was released on the 7th and encountered exceptionally strong winds. The balloon was lost to view at 13,200 meters, at which elevation the wind was 60 meters per second from the west-southwest. It was apparently stronger at still greater heights. The weather map of that date indicates an interesting relation between this strong wind and the exceedingly rapid movement of a low-pressure area centered to the northeast of Broken Arrow, accompanied by a rather steep NW.-SE. surface temperature gradient in its rear. Twenty-four hours later this low was centered 2,000 kilometers to the northeast.

The highest elevation reached during the month was 22,921 meters on the 25th. In 17 cases the maximum heights exceeded 15 kilometers; in 6 of these cases the balloons were of the largest size used, i. e., between 91 and 107 centimeters diameter, whereas, with the exception of 2 cases, all of the other balloons were smaller, i. e., 76 centimeters diameter. In the two cases referred to above the heights reached were more than 13 kilometers. It is therefore evident that the larger balloons proved to be the best for reaching high altitudes.

TEMPERATURE

The lowest temperature recorded during the series was −80.8° C. at 15,191 meters on the 13th. At that altitude the pressure record was obliterated, but the temperature trace shows a further fall to −81.7° C. at apparently 1 kilometer higher. This is the lowest temperature ever recorded on this continent, the previous record being −79.4° C. at 14.8 kilometers at St. Louis, Mo., on January 25, 1905.[1] The low mark of −81.7° C. seems to be confirmed by the observation of the following day (14th), when −77.0° C. was recorded at 16,142 meters. The weather maps of those two days show practically the entire country to have been dominated by large high-pressure areas, with centers over the southern plateau and South Atlantic States, the Canadian Northwest, and and Canadian Maritime Provinces, low-pressure areas being conspicuously absent.

Likewise, the map of January 25, 1905, shows St. Louis to have been close to the center of an exceptionally strong high-pressure area (31.1 inches). It is also found that on the day when the minimum temperature of −78.3° C. at 17,467 meters on October 9, 1927, was recorded during the sounding-balloon series at Groesbeck, Tex. (2), the country was covered by a very extensive high-pressure area.

It seems probable that these very low temperatures in the stratosphere are associated with the cold currents of "equatorial fronts."[2] Unfortunately upper air wind observations were impossible on these days because of cloud conditions over Broken Arrow, the sky being practically covered with stratus moving from the south-southwest.

The following are some of the significant features of the tropopause obtained for the more recent monthly series of sounding-balloon observations made in this country:

	Date	Mean height of tropopause	Mean temperature of tropopause	Maximum height of tropopause observed	Minimum height of tropopause observed	Range in height of tropopause observed
		Meters	° *C.*	*Meters*	*Meters*	*Meters*
Br	Dec. 1929	10,083	−54.0	12,212	7,728	4,484
Groesbeck, Tex. (2)	Oct. 1927	14,823	−65.5	17,467	11,695	5,772
Royal Center, Ind. (3)	May 1926	12,011	−58.4	15,840	8,878	6,962

The variations found between these stations are very probably the result of both a geographical and seasonal effect.

The altitude and temperature of the tropopause, for the individual observations with the corresponding dates are shown, together with the mean temperature curve, in Figure 2. The usual inverse relationship between temperature and height of the tropopause will be noted.

In Table 1 may be seen the progressive rise and fall of the tropopause during the latter part of the month, when observations of the stratosphere were obtained on several

[1] Annals Harvard College Observatory, vol. 68, pt. 1.

[2] The expression "equatorial front" is used by Willett in Bulletin National Research Council No. 79, Dynamic Meteorology, p. 229, as the antithesis, in a much modified degree, of the well-known expression "polar front."—ED.

consecutive days. It will be noted that a progressive decrease in height occurs from the 19th to the 21st; then an increase in height to the 25th, followed by another general decrease.

The direct relationship usually found between the sea-level pressure and the height of the tropopause was decidedly abnormal. During the latter part of the month, when the tropopause was low, the sea-level pressure was in general above normal, the maximum departure, +0.386 inch, occurring on the same day (21st) that the lowest tropopause was recorded. Likewise, on the 25th, when the highest tropopause was recorded, the sea-level pressure was 0.078 inch *below* normal. In this connection it is noted that there was no apparent connection between the height of the tropopause and the sea-level pressure found at Groesbeck in the series of October, 1927 (2). It would seem that this direct relationship occurs only in the higher latitudes.

In Figure 3 are shown the individual temperature-altitude curves. The surface temperature is indicated at the bottom of each curve and the temperature at the maximum altitude at the top. The wind directions whenever observed are indicated adjacent to the corresponding curves for the standard levels. Attention is invited to the curves for the 7th, 20th, 22d, and 27th, where a south wind component occurs, together with a relatively large decrease of temperature, *within* the stratosphere. This, it appears, is associated with the "equatorial front."

In general when the tropopause is high the lower part of the stratosphere is characterized by a relatively large inversion. This, of course, tends to equalize the temperature in the higher levels of the stratosphere.

The maximum average lapse rate was 0.77° C./100 meters and occurred between 6 and 7 kilometers. (See Fig. 2.) At the Groesbeck (2) this value was 0.79° C./100 meters, and at Royal Center (3), 0.71° C./100 meters. At both of the latter stations, however, this maximum average lapse rate occurred at a slightly greater altitude, viz, between 7 and 8 kilometers.

In Figure 4 are shown the free-air isotherms for the month with the dates indicated across the top. The average height of the tropopause at 10 kilometers is well brought out in this chart. The pronounced isothermal conditions in the stratosphere during the last decade of the month, when most of the higher observations were obtained, are clearly evident.

WIND

Figure 5 shows the mean wind velocity and direction curves for the month. The mean velocities and mean directions were determined independently of each other. It will be noted that the mean velocity reaches a maximum (37.5 m. p. s.) at 11 kilometers, i. e., 1 kilometer above the mean height of the tropopause. Above this height the average velocity decreases at a somewhat lower rate than that at which it increased in the lower levels which indicates a still lower value at altitudes above 21 kilometers.

The mean wind direction veers from south of west below 1,200 meters to north of west, above, up to 21 kilometers, where it is west.

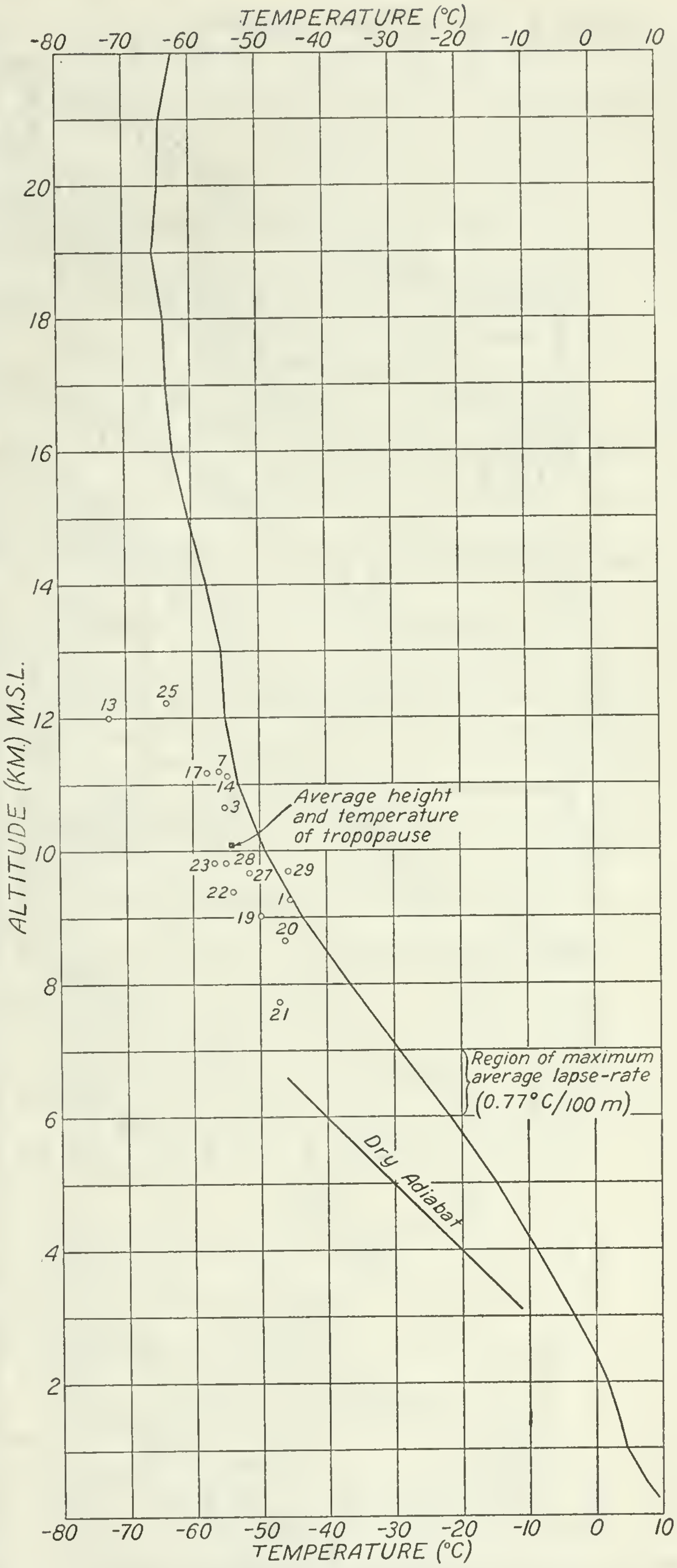


Figure 2.—Mean temperature curve (° C.) for December, 1929, Broken Arrow, Okla. (Circles indicate height and temperature of tropopause with corresponding dates)

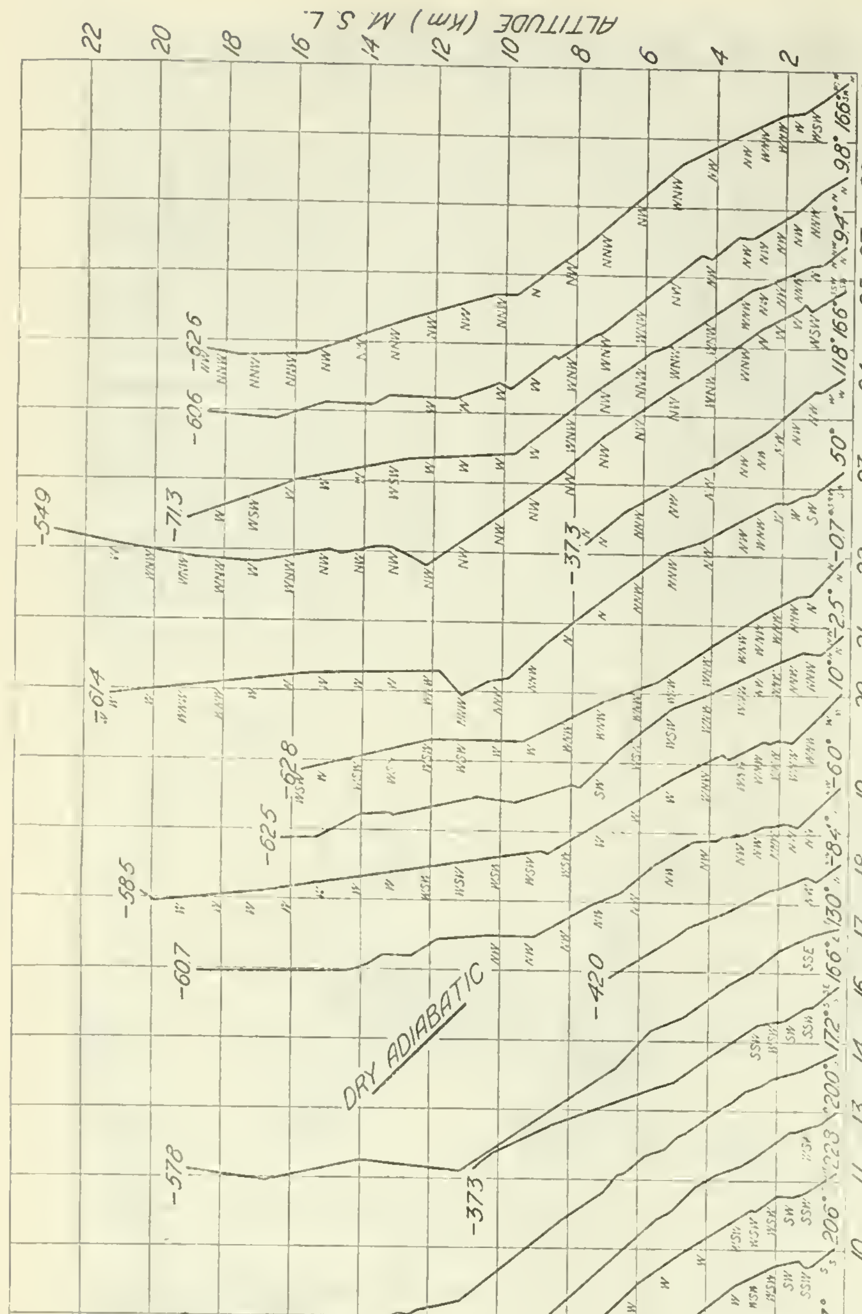


FIGURE 3.—Temperature-altitude curves for individual observations made at Broken Arrow, Okla., during December, 1929. (Dates indicated below.) (Figures at bottom and top of curves indicate temperatures (° C.) at surface and at maximum altitudes; abscissa value of each square corresponds to 20° C. of temperature)

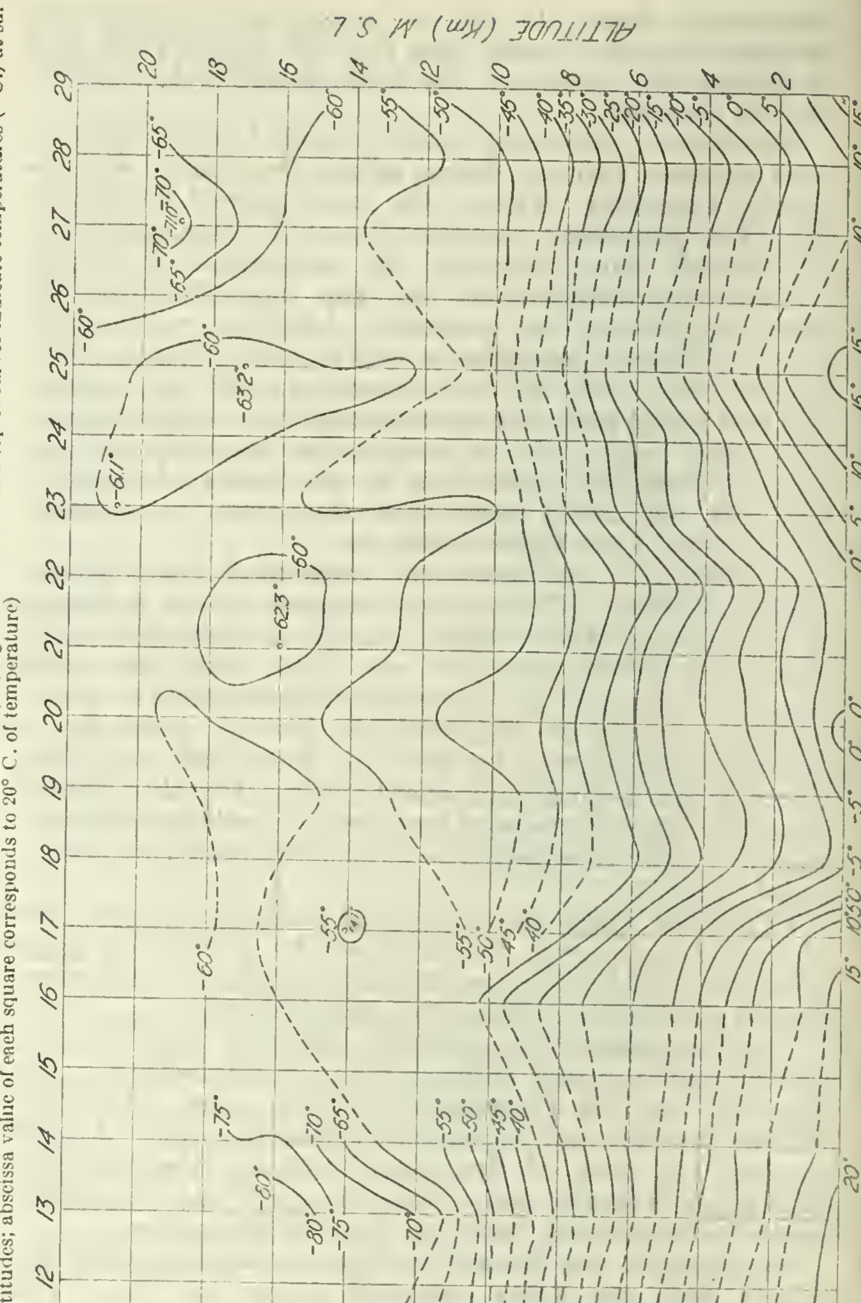


FIGURE 4.—Free-air isotherms (° C.) observed at Broken Arrow, Okla., during December, 1929. (Broken lines drawn between missing days with observations) (Dates indicated at top)

The individual wind velocity curves are shown in Figure 6. The general increase in velocity from the ground to the tropopause is evident and also the decrease within the stratosphere.

Figure 7 shows the wind-direction curves for each observation. The rapid shift to northwesterly between the surface and 2 kilometers is clearly indicated. In no case was a shift to easterly found at the highest levels as at Groesbeck in October, 1927 (2). However, it will be noted that in three cases (3d, 10th, and 29th) the direction at the upper extremities of the curves reaching to high altitudes (above 18 kilometers) veers toward the north. This characteristic is very similar to the curves for Groesbeck (2), where the veering continued past north into east. It seems very probable, therefore, that at somewhat greater heights the upper easterly winds would have been observed at Broken Arrow.

RELATIVE HUMIDITY

Figure 8 shows the mean relative humidity for the month. However, on account of the increasing lag of the hair hygrometric element at temperatures below −15° C., the mean humidity values must be accepted with reservation above 5 kilometers.

For references to previous sounding-balloon series made in this country see MONTHLY WEATHER REVIEW, June, 1929, pages 231–246, and July, 1927, page 302.

TABLE 1.—*Summary of sounding-balloon observations made at Broken Arrow, Okla., during December, 1929*

Date	Time of release, 90th mer.	Stratosphere: Height of base, M. S. L.	Stratosphere: Temperature at base	Maximum height reached, M. S. L.	Minimum temperature recorded	Theodolite observations: 2-theodolite	Theodolite observations: 1-theodolite	Meteorograph found: Distance from station	Meteorograph found: Direction from station
		M.	*° C.*	*M.*	*° C.*	*Min.*	*Min.*	*Km.*	
1	4:23 p	9, 272	−45. 4	12, 327	−52. 7	4	16	300	ENE.
2	4:24 p	--------	--------	13, 175	--------	60	--------	(1)	
3	4:04 p	10, 639	−55. 0	15, 957	−64. 0	49	82	145	SE.
4	4:21 p	--------	--------	[2] 19, 600	−54. 1	72	78	84	SE.
5	4:07 p	--------	--------	10, 759	−57. 6	21	28	250	E.
6	4:13 p	--------	--------	--------	--------	5	--------	110	ENE.
7	4:22 p	11, 206	−55. 9	16, 181	−65. 5	53	55	450	ENE.
8	3:39 p	--------	--------	9, 900	−46. 8	16	22	270	E.
9	3:59 p	--------	--------	5, 783	−11. 6	10	21	385	E.
10	3:58 p	--------	--------	[2] 20, 300	−67. 6	80	85	127	E.
11	4:17 p	--------	--------	9, 402	−44. 0	20	30	127	E.
12	4:20 p	--------	--------	--------	--------	0	15	(1)	
13	4:19 p	12, 000	−72. 5	15, 191	−81. 7	2	5	110	E.
14	4:25 p	11, 112	−55. 2	17, 304	−77. 0	0	1	110	E.
15	4:03 p	--------	--------	--------	--------	0	1	(1)	
16	4:12 p	--------	--------	10, 764	−37. 3	5	14	63	E.
17	7:27 a	11, 072	−57. 8	18, 962	−60. 7	0	4	85	N.
17	4:21 p	--------	--------	--------	--------	1	--------	(1)	
18	7:52 a	--------	--------	--------	--------	3	--------	(1)	
18	4:45 p	--------	--------	6, 874	−42. 0	0	5	120	SE.
19	7:30 a	--------	--------	--------	--------	--------	--------	(1)	
19	4:10 p	8, 999	−50. 1	18, 704	−60. 7	48	51	185	SE.
20	4:01 p	8, 652	−46. 2	20, 355	−60. 9	[3] 83	--------	145	ESE.
21	4:26 p	7, 728	−47. 1	16, 334	−62. 5	21	--------	125	ENE.
22	3:32 p	9, 386	−54. 1	17, 790	−62. 8	53	66	170	E.
23	4:12 p	9, 820	−56. 8	21, 289	−61. 4	78	86	125	SE.
24	4:04 p	--------	--------	[2] 13, 070	−37. 3	40	50	365	ESE.
25	3:49 p	12, 212	−63. 8	22, 921	−63. 8	90	--------	150	ESE.
26	4:04 p	--------	--------	7, 420	--------	27	--------	(1)	
27	4:21 p	9, 660	−51. 5	19, 078	−71. 3	69	--------	160	E.
28	4:22	9, 807	−53. 0	18, 519	−62. 3	46	56	190	ESE.
29	3:44 p	9, 686	−45. 8	18, 550	−64. 1	74	83	136	SE.
30	4:08 p	--------	--------	15, 611	--------	65	73	(1)	
31	4:10 p	--------	--------	[1] 5, 183	(4)	21	23	160	NE.

[1] Not found. [2] Maximum altitude from 2-theodolite observation.

[3] In the two theodolite observation of the 20th, the balloon was observed until its horizontal distance from the place of observation was 122 km., at which time the balloon had reached an altitude of 18 kms. and had been in the air 83 minutes. So far as is known, this is the greatest horizontal distance to which a balloon has ever been observed by two theodolites.

[4] Record sheet lost.

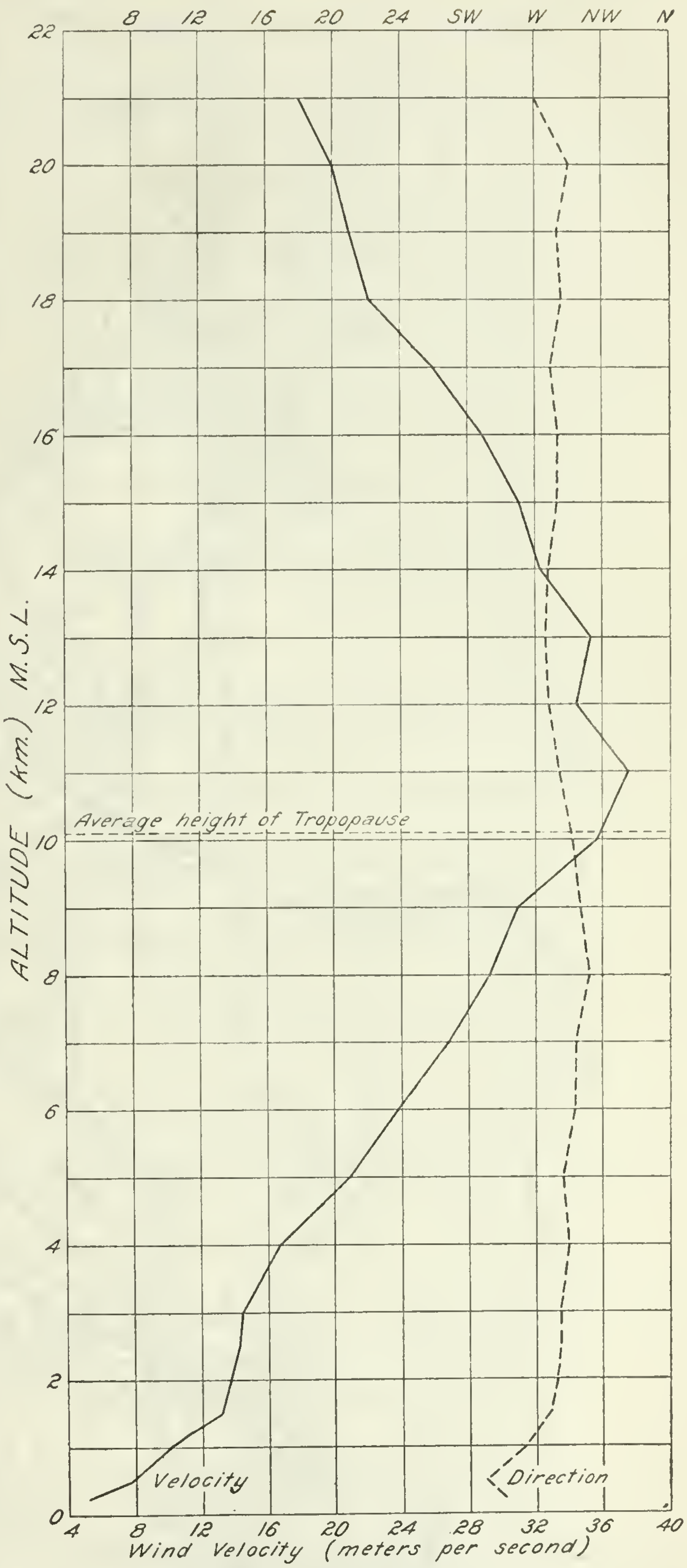


FIGURE 5.—Mean wind velocity (m.p.s.) and direction curves observed at Broken Arrow, Okla., during December, 1929

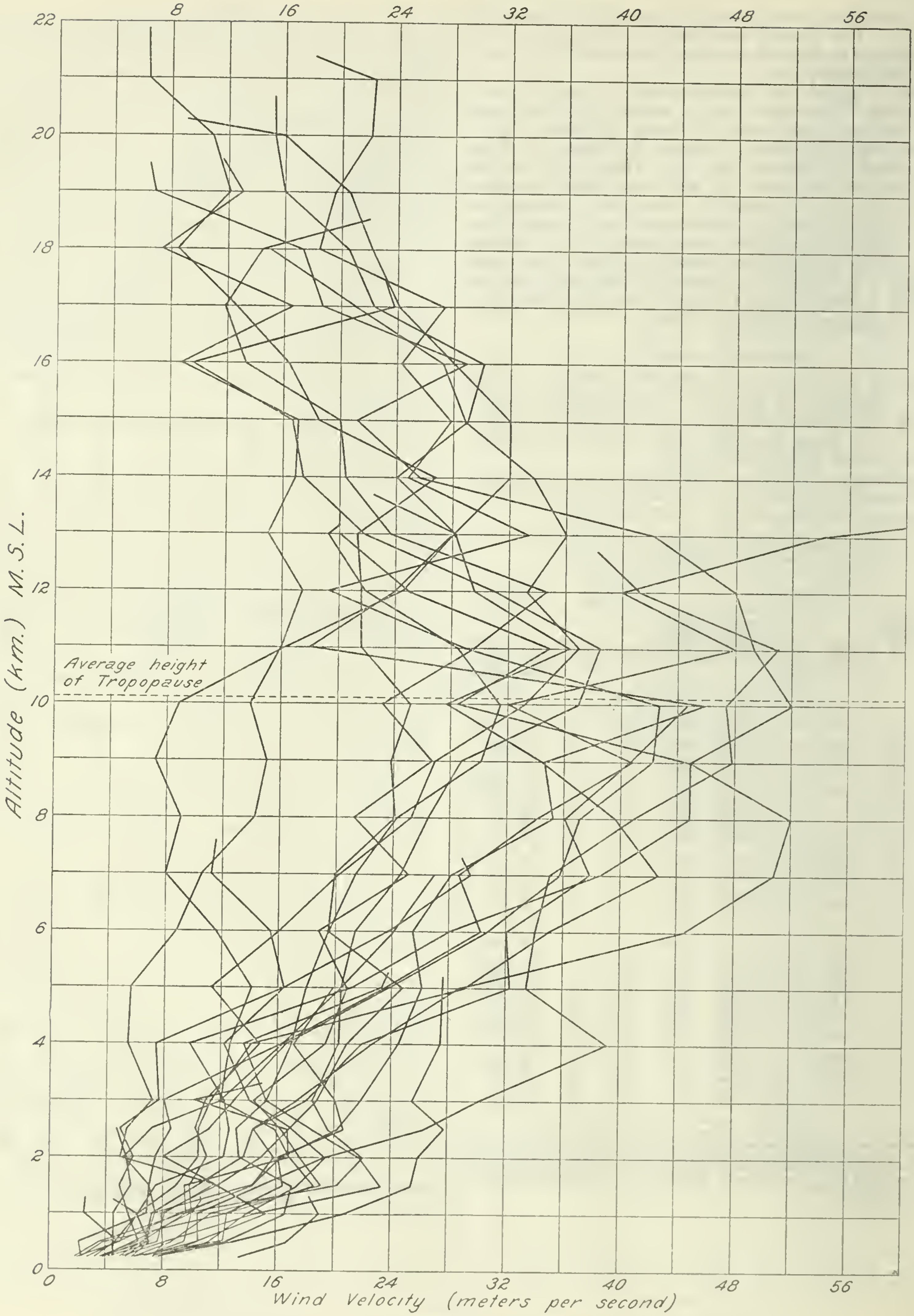


FIGURE 6.—Wind-velocity curves for individual observations made at Broken Arrow, Okla., during December, 1929

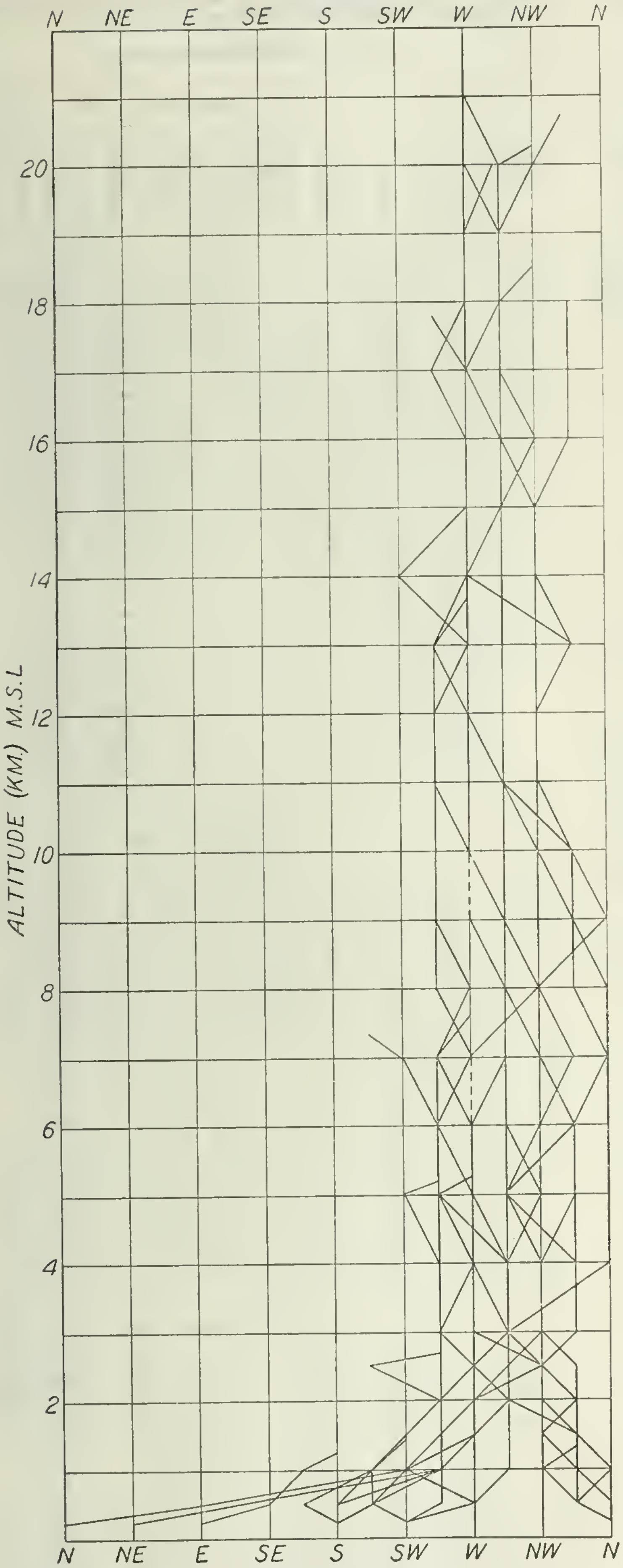


FIGURE 7.—Wind-direction curves for individual observations made at Broken Arrow, Okla., during December, 1929

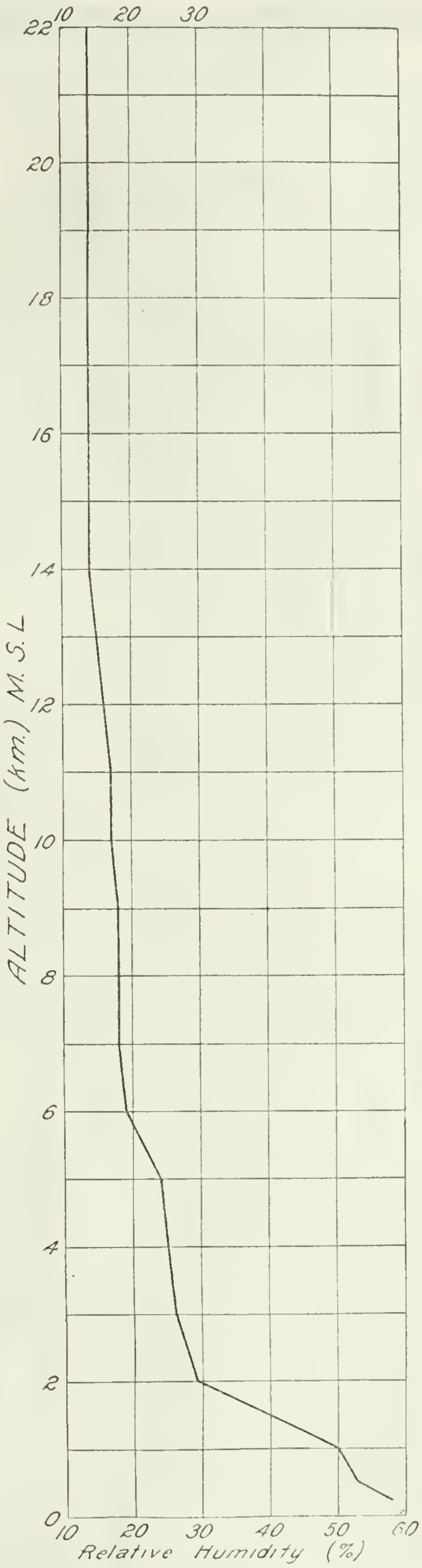


FIGURE 8.—Mean relative humidity curve for December, 1929, Broken Arrow, Okla.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*

DECEMBER 1, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:23	233	991.1	1.4	------	78	5.27	n.	7.6	1 Ci. Cu. W.; 5 A. Cu., W.; 3 St., N.
	500	958.6	−1.0	------	85	4.79	n.	10.4	
4:27	943	906.5	−5.0	0.68	96	3.87	n.	15.4	
	1,000	900.0	−4.9	------	89	3.62	n.	15.6	
4:28	1,065	892.7	−4.7	−0.25	80	3.31	n.	14.3	
4:29	1,327	863.3	−4.8	0.04	93	3.81	nnw.	13.3	
	1,500	844.5	−5.7	------	90	3.42	nnw.	11.8	
4:31	1,785	814.4	−7.3	0.55	84	2.78	nnw.	11.4	
	2,000	792.2	−6.7	------	72	2.51	nnw.	14.8	
4:34	2,205	771.6	−5.9	−0.33	61	2.28	nw.	18.1	
	2,500	743.1	−7.5	------	58	1.89	nw.	16.7	
4:36	2,720	722.4	−8.7	0.54	56	1.64	nw.	11.8	
	3,000	696.9	−9.5	------	66	1.81	w.	10.2	
4:42	3,825	626.1	−12.0	0.30	97	2.12	------	------	
4:43	3,886	621.2	−11.1	−1.48	94	2.24	------	------	
	4,000	611.9	−11.8	------	94	2.10	------	------	
4:46	4,602	565.6	−15.3	0.59	94	1.52	------	------	
	5,000	537.0	−16.2	------	76	1.13	------	------	
4:49	5,084	530.6	−16.4	0.23	72	1.06	------	------	
	6,000	469.9	−24.4	------	60	0.41	------	------	
4:55	6,269	452.3	−26.7	0.87	57	0.31	------	------	
	7,000	408.3	−32.0	------	62	0.19	------	------	
5:02	7.816	363.4	−37.9	0.72	68	0.11	------	------	
	8,000	354.0	−37.9	------	61	0.10	------	------	
5:03	8,039	352.1	−37.9	0.00	60	0.10	------	------	
	9,000	306.2	−43.7	------	55	0.05	------	------	
5:07	9,272	294.5	−45.4	0.61	54	0.04	------	------	Tropopause.
5:09	9,604	279.8	−45.4	0.00	51	0.04	------	------	
5:10	9,689	276.6	−44.3	−1.29	50	0.04	------	------	
	10,000	264.3	−45.3	------	50	0.03	------	------	
	11,000	227.8	−48.5	------	49	0.02	------	------	
	12,000	195.6	−51.7	------	47	0.02	------	------	
5:23	12,327	186.3	−52.7	0.32	47	0.01	------	------	

DECEMBER 3, 1929

P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:04	233	994.8	9.8	------	36	4.36	w.	3.6	Cloudless.
	500	963.2	7.8	------	37	3.91	w.	6.9	
4:06	586	953.0	7.1	0.76	37	3.73	w.	7.2	
	1,000	906.0	3.8	------	41	3.29	wnw.	7.2	
4:09	1,171	887.2	2.4	0.80	42	3.05	wnw.	8.9	
4:10	1,345	868.2	3.3	−0.52	40	3.10	wnw.	12.2	
	1,500	852.2	2.8	------	43	3.21	wnw.	14.2	
4:11	1,560	845.6	2.6	0.33	44	3.24	wnw.	15.2	
	2,000	800.9	2.6	------	44	3.24	wnw.	16.2	
4:14	2,063	794.5	2.6	0.00	44	3.24	wnw.	16.0	
4:15	2,296	771.9	1.7	0.39	43	2.97	wnw.	17.6	
	2,500	752.7	1.6	------	41	2.81	wnw.	20.2	
4:17	2,656	738.3	1.5	0.06	40	2.72	wnw.	21.4	
	3,000	707.3	−0.6	------	39	2.27	wnw.	21.8	
4:19	3,208	689.1	−1.9	0.62	38	1.99	wnw.	22.2	
4:20	3,403	672.6	−1.9	0.00	36	1.88	wnw.	22.2	
	4,000	623.6	−5.1	------	34	1.36	n.	24.4	
4:25	4,582	578.9	−8.2	0.53	33	1.01	n.	24.8	
	5,000	548.4	−11.5	------	34	0.78	n.	26.1	
4:31	5,870	489.1	−18.3	0.78	36	0.44	n.	25.5	
	6,000	480.5	−19.4	------	36	0.40	n.	25.4	
	7,000	419.5	−27.7	------	36	0.18	n.	28.0	
4:36	7,141	411.3	−28.9	0.83	36	0.16	nnw.	27.3	
	8,000	364.4	−36.3	------	35	0.07	nnw.	35.2	
4:43	8,847	322.9	−43.5	0.86	35	0.03	nnw.	34.4	
	9,000	315.7	−44.5	------	35	0.03	nnw.	34.6	
	10,000	272.2	−50.9	------	34	0.01	nw.	45.8	
4:50	10,639	246.8	−55.0	0.61	34	0.01	nw.	39.4	Tropopause.
4:51	10,998	233.8	−53.9	−0.31	34	0.01	nw.	18.0	
	11,000	233.7	−53.9	------	34	0.01	nw.	18.0	
	12,000	200.9	−54.5	------	34	0.01	nw.	23.8	
4:56	12,721	179.8	−55.0	0.06	34	0.01	nnw.	29.4	
	13,000	172.1	−55.6	------	34	0.01	nnw.	28.0	
	14,000	147.5	−57.8	------	34	(1)	w.	24.0	
5:02	14,372	139.2	−58.6	0.22	34	(1)	wnw.	24.3	
	15,000	126.1	−60.7	------	34	(1)	wnw.	29.0	
5:08	15,957	108.2	−64.0	0.34	34	(1)	wnw.	30.1	
	16,000	------	------	------	------	------	nw.	30.4	
	17,000	------	------	------	------	------	wnw.	22.5	
	18,000	------	------	------	------	------	wnw.	21.6	
	19,000	------	------	------	------	------	wnw.	16.0	
	20,000	------	------	------	------	------	nw.	15.3	
5:26	20,690	------	------	------	------	------	nnw.	15.2	

Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 4, 1929

Time, 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:21	233	995.5	13.4	------	39	6.00	s.	4.0	Few Ci., WNW.
	500	964.3	11.2	------	44	5.85	ssw.	7.6	
4:24	851	924.4	8.2	0.84	51	5.54	wsw.	7.1	
	1,000	907.9	9.2	------	44	5.12	wsw.	8.0	
4:25	1,167	889.8	10.4	−0.70	37	4.67	wsw.	9.4	
	1,500	854.5	8.8	------	------	------	wsw.	10.0	
4:27	1,565	848.0	8.5	0.48	------	------	wsw.	9.1	
4:28	1,681	836.1	8.5	0.00	------	------	wsw.	7.3	
	2,000	801.3	6.8	------	------	------	w.	4.9	
	2,500	753.4	4.3	------	------	------	nw.	5.4	
4:32	2,548	752.1	4.0	0.52	------	------	nw.	5.4	
	3,000	711.1	1.4	------	------	------	wnw.	7.2	
	4,000	627.2	−4.5	------	------	------	wnw.	5.4	
	5,000	552.0	−10.3	------	------	------	nw.	5.6	
4:44	5,171	540.1	−11.3	0.58	------	------	nw.	5.9	
	6,000	483.9	−18.1	------	------	------	nw.	8.8	
4:51	6,971	424.7	−26.1	0.82	------	------	nw.	10.4	
	7,000	423.2	−26.3	------	------	------	nw.	10.5	
	8,000	367.7	−34.7	------	------	------	nw.	14.2	
	9,000	318.6	−43.1	------	------	------	nw.	15.0	
4:59	9,323	304.1	−45.8	0.84	------	------	nw.	14.2	
	10,000	275.1	−51.9	------	------	------	nw.	13.8	
5:02	10,248	264.7	−54.1	0.90	------	------	nw.	13.0	
	11,000	------	------	------	------	------	nw.	15.8	
	12,000	------	------	------	------	------	wnw.	17.4	
	13,000	------	------	------	------	------	wnw.	15.1	
	14,000	------	------	------	------	------	wnw.	16.9	
	15,000	------	------	------	------	------	wnw.	17.0	
	16,000	------	------	------	------	------	w.	8.8	
	17,000	------	------	------	------	------	wnw.	16.6	
	18,000	------	------	------	------	------	wnw.	7.3	
	19,000	------	------	------	------	------	wnw.	13.0	
5:40	19,600	------	------	------	------	------	wnw.	11.5	

DECEMBER 5, 1929

P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:07	233	985.7	15.7	------	34	6.07	sw.	7.2	6 Ci., W.; 2 Ci. Cu., W.
	500	955.1	13.9	------	34	5.40	ssw.	8.1	
4:10	830	918.2	11.7	0.67	35	4.81	ssw.	13.6	
	1,000	899.8	10.6	------	37	4.73	sw.	14.5	
4:12	1,131	885.8	9.8	0.63	39	4.73	sw.	14.7	
	1,500	847.4	9.6	------	35	4.18	wsw.	23.3	
	2,000	797.8	9.3	------	31	3.63	wsw.	21.8	
4:17	2,065	791.4	9.3	0.05	30	3.51	wsw.	21.6	
	2,500	750.9	9.3	------	26	3.04	w.	18.4	
4:20	2,560	745.5	9.3	0.00	26	3.04	w.	17.8	
	3,000	706.8	5.9	------	25	2.32	wsw.	15.2	
4:25	3,503	664.5	2.1	0.76	24	1.70	wsw.	15.2	
4:26	3,607	656.0	2.3	−0.19	22	1.59	wsw.	14.7	
	4,000	624.5	−0.7	------	23	1.33	w.	13.6	
4:34	5,005	549.8	−8.3	0.76	24	0.73	wsw.	23.2	
	6,000	483.1	−16.1	------	25	0.38	------	------	
4:42	6,431	456.6	−19.5	0.79	25	0.28	------	------	
	7,000	422.6	−24.3	------	26	0.18	------	------	
4:50	7,949	371.0	−32.3	0.84	27	0.08	------	------	
	8,000	368.2	−32.6	------	27	0.08	------	------	
4:52	8,366	350.1	−34.4	0.50	27	0.06	------	------	
	9,000	319.6	−40.7	------	27	0.03	------	------	
	10,000	276.1	−50.5	------	26	0.01	------	------	
4:58	10,179	268.6	−52.3	0.99	26	0.01	------	------	
5:01	10,759	245.8	−57.6	0.91	25	(1)	------	------	

DECEMBER 7, 1929

P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:22	233	984.4	2.6	------	78	5.74	ne.	2.2	Cloudless.
	500	952.3	0.7	------	87	5.59	ese.	2.0	
4:26	856	910.9	−1.9	0.72	100	5.23	w.	5.1	
	1,000	894.8	1.1	------	84	5.55	wsw.	6.8	
4:27	1,119	881.7	3.6	−2.09	70	5.53	w.	7.7	
	1,500	840.7	1.9	------	65	4.55	w.	7.0	
	2,000	790.0	−0.3	------	58	3.46	wnw.	7.4	
	2,500	742.4	−2.5	------	52	2.58	w.	8.5	
4:35	2,844	711.1	−4.0	0.44	47	2.06	wnw.	8.2	
	3,000	697.2	−5.0	------	47	1.89	wnw.	8.0	
	4,000	612.8	−11.7	------	46	1.01	w.	16.2	
4:42	4,130	602.6	−12.6	0.67	46	0.96	w.	18.2	
4:43	4,555	570.0	−11.4	−0.28	48	1.11	w.	23.8	
	5,000	537.8	−14.3	------	45	0.80	w.	23.4	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 7, 1929—Continued

Time, 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P.m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
4:48	5,636	494.4	−18.5	0.66	40	0.48	wsw.	28.4	
	6,000	470.9	−20.8	------	41	0.40	w.	30.2	
4:52	6,982	411.7	−27.0	0.63	45	0.24	wsw.	28.6	
	7,000	410.8	−27.1	------	45	0.23	wsw.	28.6	
	8,000	357.3	−34.3	------	42	0.10	w.	34.1	
4:58	8,784	319.6	−39.9	0.72	40	0.05	wsw.	38.8	
	9,000	309.5	−41.3	------	40	0.04	wsw.	40.7	
	10,000	267.2	−47.9	------	39	0.02	wsw.	35.2	
	11,000	229.9	−54.5	------	38	0.01	wsw.	48.1	
5:07	11,206	222.5	−55.9	0.66	38	0.01	wsw.	49.9	Tropopause.
	12,000	197.4	−55.5	------	37	0.01	wsw.	39.9	
	13,000	169.0	−54.9	------	36	0.01	wsw.	54.0	
5:16	13,356	159.9	−54.7	−0.06	35	0.01	------	------	
	14,000	149.8	−57.2	------	35	0.01	------	------	
	15,000	123.4	−61.0	------	34	(1)	------	------	
	16,000	105.6	−64.8	------	33	(1)	------	------	
5:37	16,181	102.6	−65.5	0.38	33	(1)	------	------	

DECEMBER 8, 1929

Time, 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
3:39	233	986.2	9.3	------	70	8.20	se.	5.4	10 Ci., WNW.
	500	955.0	7.8	------	80	8.46	------	------	
3:42	873	912.7	5.6	0.58	95	8.61	------	------	
	1,000	898.6	5.7	------	98	8.98	------	------	
3:43	1,067	891.2	5.7	−0.05	100	9.16	------	------	
3:45	1,425	853.4	11.4	−1.59	45	6.07	------	------	
	1,500	845.8	11.3	------	43	5.76	------	------	
3:47	1,819	814.1	11.1	0.08	35	4.62	------	------	
	2,000	796.4	9.9	------	32	3.90	------	------	
	2,500	749.5	6.7	------	25	2.45	------	------	
3:50	2,705	731.1	5.4	0.64	22	1.97	------	------	
3:51	2,817	721.2	5.0	0.36	22	1.92	------	------	
3:52	2,978	707.4	3.6	0.87	21	1.66	------	------	
	3,000	705.5	3.6	------	21	1.66	------	------	
3:53	3,233	685.3	3.8	−0.08	19	1.52	------	------	
	4,000	622.9	−1.4	------	19	1.03	------	------	
4:01	4,801	563.0	−6.9	0.68	8	0.62	------	------	
	5,000	548.9	−8.1	------	18	0.56	------	------	
	6,000	482.2	−14.0	------	17	0.31	------	------	
4:06	6,126	474.5	−14.7	0.59	17	0.29	------	------	
	7,000	422.2	−24.4	------	16	0.11	------	------	
4:11	7,170	412.5	−26.3	1.11	16	0.09	------	------	
	8,000	367.3	−32.6	------	15	0.04	------	------	
4:16	8,611	336.9	−37.3	0.76	15	0.03	------	------	
	9,000	319.0	−40.2	------	15	0.02	------	------	
4:20	9,900	280.2	−46.8	0.74	15	0.01	------	------	

DECEMBER 9, 1929

Time, 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
3:59	233	988.5	10.7	------	74	9.52	n.	2.2	10 Ci. St., W.
4:00	465	961.3	8.5	0.95	92	10.21	ne.	2.8	
	500	957.2	8.5	------	93	10.32	e.	3.8	
4:01	675	937.3	8.4	0.05	98	10.80	ssw.	7.6	
	1,000	901.4	11.6	------	67	9.15	sw.	12.5	
4:04	1,419	857.5	15.7	−0.98	28	5.00	wsw.	16.4	
	1,500	849.3	15.7	------	28	5.00	wsw.	16.4	
4:05	1,597	839.9	15.6	0.06	27	4.79	wsw.	16.2	
	2,000	800.4	13.2	------	26	3.95	wsw.	16.1	
	2,500	754.0	10.1	------	25	3.09	w.	20.6	
4:10	2,734	733.2	8.7	0.61	24	2.70	w.	21.6	
4:13	2,978	711.9	6.7	0.82	23	2.26	wsw.	20.0	
	3,000	710.0	6.6	------	23	2.24	wsw.	20.0	
4:16	3,960	630.9	0.8	0.60	31	2.01	w.	16.6	
	4,000	627.8	0.5	------	31	1.96	w.	17.0	
	5,000	553.5	−6.3	------	32	1.16	w.	19.8	
4:23	5,783	500.6	−11.6	0.68	33	0.75	------	------	

DECEMBER 10, 1929

Time, 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
3:58	233	938.2	20.6	------	60	14.57	s.	5.8	4 Ci., WSW.
	500	958.0	18.5	------	75	15.98	s.	12.2	
4:01	878	916.8	15.6	0.78	96	17.02	ssw.	11.3	
	1,000	903.7	15.1	------	90	15.45	ssw.	12.5	
4:02	1,005	903.2	15.1	0.39	90	15.45	ssw.	12.6	
4:03	1,106	892.3	15.2	−0.10	55	9.50	sw.	15.2	
4:04	1,294	872.8	17.0	−0.96	40	7.75	sw.	18.0	
	1,500	852.1	16.6	------	37	6.99	sw.	18.6	
4:07	1,965	806.6	15.6	0.21	30	5.32	wsw.	16.9	
	2,000	803.3	15.4	------	30	5.25	wsw.	16.8	
	2,500	757.0	12.9	------	29	4.32	wsw.	15.8	
	3,000	713.2	10.3	------	28	3.51	w.	12.0	
4:12	3,158	699.8	9.5	0.51	28	3.32	w.	11.5	
	4,000	631.5	2.9	------	25	1.88	w.	12.6	
	5,000	558.1	−5.0	------	22	0.89	w.	14.1	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 10, 1929—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P.m.	*M.*	*Mb.*	°*C.*		*P.ct.*	*Mb.*		*M.p.s.*	
4:22	5,430	528.7	−8.4	0.79	20	0.60	wsw.	13.8	
	6,000	490.7	−13.4	------	20	0.39	wsw.	11.6	
	7,000	429.4	−22.3	------	19	0.16	w.	8.0	
	8,000	374.3	−31.1	------	19	0.06	nw.	9.0	
	9,000	324.5	−39.9	------	18	0.02	wnw.	7.2	
4:37	9,486	302.6	−44.2	0.88	18	0.01	wnw.	8.4	
	10,000	280.1	−49.5	------	18	0.01	w.	8.8	
	11,000	240.1	−59.7	------	17	(1)	w.	16.3	
4:45	11,775	212.1	−67.6	1.02	16	(1)	w.	21.9	
	12,000	------	------	------	------	------	w.	24.5	
	13,000	------	------	------	------	------	wsw.	28.0	
	14,000	------	------	------	------	------	w.	32.0	
	15,000	------	------	------	------	------	w.	32.0	
	16,000	------	------	------	------	------	w.	28.1	
	17,000	------	------	------	------	------	w.	24.1	
	18,000	------	------	------	------	------	w.	22.2	
	19,000	------	------	------	------	------	w.	20.6	
	20,000	------	------	------	------	------	wnw.	15.9	
5:19	20,300	------	------	------	------	------	nw.	9.0	

DECEMBER 11, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:17	233	984.3	22.8	------	62	17.22	s.	7.6	3 Ci. St., W.; 6 Ci., W.
	500	954.5	21.0	------	71	17.66	ssw.	11.2	
	1,000	900.8	17.5	------	87	17.41	ssw.	13.9	
4:21	1,106	889.8	16.8	0.69	90	17.23	sw.	14.5	
4:22	1,235	876.4	16.4	0.31	88	16.42	sw.	15.1	
4:23	1,440	855.3	15.7	0.34	65	11.60	sw.	16.9	
	1,500	849.4	15.7	------	61	10.88	sw.	17.4	
4:25	1,918	808.6	16.0	−0.06	36	6.55	wsw.	19.0	
	2,000	800.9	15.4	------	38	6.65	wsw.	19.4	
4:26	2,238	778.6	13.5	0.78	43	6.66	wsw.	19.6	
	2,500	754.7	11.9	------	36	5.01	wsw.	17.0	
4:28	2,566	748.7	11.5	0.61	34	4.61	wsw.	16.6	
4:29	2,692	737.5	11.7	−0.16	32	4.40	wsw.	16.2	
	3,000	710.7	9.8	------	31	3.76	wsw.	14.0	
	4,000	629.5	3.5	------	28	2.20	w.	12.2	
4:37	4,778	571.9	−1.4	0.63	25	1.36	w.	16.0	
	5,000	556.1	−3.0	------	25	1.19	w.	16.4	
4:41	5,887	496.8	−9.4	0.72	23	0.63	w.	16.4	
	6,000	489.4	−10.5	------	23	0.58	w.	15.4	
	7,000	429.4	−20.0	------	24	0.25	wsw.	11.2	
4:47	7,325	411.3	−23.1	0.95	24	0.18	w.	10.9	
	8,000	375.0	−29.9	------	25	0.10	------	------	
	9,000	326.1	−40.0	------	27	0.04	------	------	
4:54	9,402	307.9	−44.0	1.01	28	0.02	------	------	

DECEMBER 13, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:19	233	991.9	20.0	------	83	19.42	s.	6.7	2 Ci. St., WSW.; 8 St., SSW.
	500	961.7	18.2	------	92	19.24	ssw.	9.5	
4:22	738	935.3	16.6	0.67	100	18.90	ssw.	11.6	
4:23	994	907.6	16.0	0.23	88	16.01	wsw.	10.0	
	1,000	907.0	16.0	------	88	16.01	wsw.	10.0	
4:24	1,415	863.8	14.6	0.33	99	15.79	------	------	
	1,500	855.1	14.5	------	90	14.86	------	------	[2] Lowest temperature recorded; altitude approximately 16,476 m., M. S. L., based on ascensional rate.
4:25	1,589	846.2	14.4	0.11	85	13.95	------	------	
	2,000	805.8	11.4	------	82	11.05	------	------	
	2,500	758.8	7.7	------	79	8.30	------	------	
4:30	2,633	746.8	6.7	0.74	78	7.65	------	------	
	3,000	714.1	4.5	------	54	4.55	------	------	
4:32	3,031	711.2	4.3	0.60	52	4.32	------	------	
4:35	3,705	654.6	2.0	0.34	40	2.82	------	------	
	4,000	631.1	0.2	------	40	2.48	------	------	
4:37	4,313	606.9	−1.8	0.62	39	2.06	------	------	
	5,000	556.4	−8.7	------	43	1.26	------	------	
4:41	5,028	554.4	−9.0	1.01	43	1.23	------	------	
4:42	5,454	524.9	−11.3	0.54	36	0.84	------	------	
	6,000	488.8	−16.4	------	33	0.49	------	------	
4:45	6,032	486.5	−16.7	0.93	33	0.47	------	------	
	7,000	427.4	−25.5	------	32	0.19	------	------	
4:52	7,457	401.7	−29.7	0.84	31	0.12	------	------	
	8,000	372.3	−34.4	------	30	0.07	------	------	
4:57	8,760	334.3	−41.0	0.87	29	0.03	------	------	
	9,000	322.7	−43.2	------	29	0.03	------	------	
	10,000	278.5	−52.2	------	30	0.01	------	------	
5:03	10,371	263.2	−55.6	0.91	30	0.01	------	------	
	11,000	239.2	−62.1	------	30	(1)	------	------	
5:10	12,000	204.1	−72.5	1.04	31	(1)	------	------	Tropopause.
5:13	12,592	185.5	−69.1	−0.57	31	(1)	------	------	
5:15	12,958	174.9	−65.9	−0.87	30	(1)	------	------	
	13,000	173.5	−66.2	------	30	(1)	------	------	
5:19	13,905	150.3	−73.1	0.76	28	(1)	------	------	
	14,000	148.0	−73.7	------	28	(1)	------	------	
	15,000	125.2	−79.2	------	27	(1)	------	------	
5:28	15,191	121.3	−80.8	0.60	27	(1)	------	------	
5:30	------	------	−81.7[1]	------	------	------	------	------	

[2] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 14, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:25	233	993.7	17.2		95	18.65	s.	3.1	1 A. St., SW.; 9 St., SSW.
	500	963.0	15.9		95	17.17			
	1,000	908.0	13.5		96	14.86			
4:30	1,278	878.4	12.1	0.49	96	13.56			
	1,500	855.3	11.4		73	9.84			
4:31	1,513	854.1	11.4	0.30	72	9.71			
	2,000	805.7	10.0		65	7.98			
4:34	2,108	795.3	9.7	0.29	63	7.58			
4:35	2,463	762.1	7.4	0.65	60	6.18			
	2,500	758.7	7.3		58	5.93			
4:37	2,891	723.4	5.9	0.35	35	3.25			
	3,000	713.8	5.0		34	2.96			
4:39	3,292	688.5	2.7	0.80	33	2.45			
4:40	3,683	656.2	0.3	0.61	65	4.06			
	4,000	630.9	−1.9		75	3.92			
4:44	4,626	582.9	−6.3	0.70	96	3.47			
4:45	4,847	566.9	−7.6	0.59	84	2.71			
	5,000	555.8	−9.0		79	2.26			
4:47	5,214	540.5	−11.0	0.93	72	1.73			
4:49	5,785	502.1	−12.9	0.33	46	0.93			
4:50	5,925	492.8	−14.2	0.93	47	0.85			
	6,000	488.0	−14.8		46	0.78			
4:51	6,394	463.1	−18.1	0.83	43	0.54			
4:52	6,528	455.2	−18.5	0.30	35	0.42			
4:55	6,957	429.8	−23.4	1.14	26	0.20			
	7,000	427.2	−23.7		26	0.19			
	8,000	372.7	−30.6		32	0.12			
4:58	8,260	359.2	−32.4	0.69	34	0.10			
	9,000	323.7	−38.3		36	0.06			
5:03	9,767	289.8	−44.5	0.80	38	0.03			
	10,000	280.1	−46.4		38	0.02			
	11,000	241.5	−54.3		39	0.01			
5:07	11,112	237.2	−55.2	0.80	39	0.01			Tropopause.
	12,000	207.3	−57.3		35	0.01			
5:11	12,316	197.4	−58.0	0.23	34	(1)			
5:13	12,523	191.0	−59.1	0.53	33	(1)			
5:15	12,837	181.8	−58.8	−0.10	33	(1)			
	13,000	177.2	−59.5		33	(1)			
5:18	13,556	162.8	−61.8	0.42	31	(1)			
	14,000	151.7	−65.0		31	(1)			
5:21	14,212	146.8	−66.5	0.72	31	(1)			
	15,000	129.2	−71.1		31	(1)			
5:26	15,144	126.1	−71.9	0.58	31	(1)			
	16,000	109.6	−76.3		30	(1)			
5:32	16,142	106.9	−77.0	0.51	30	(1)			
5:33	16,543	100.3	−76.6	−0.10	30	(1)			
	17,000	93.1	−74.7		31	(1)			
5:42	17,324	88.2	−73.4	−0.41	31	(1)			

DECEMBER 16, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:12	233	985.9	16.6		76	14.36	s.	4.5	4 St. Cu., SSW., at 4:12 p. m., increasing to 9 St. Cu., SSW., by 4:20 p. m.
	500	955.3	14.4		85	13.95	sse.	4.5	
4:17	952	905.3	10.6	0.83	100	12.78	ssw.	4.5	
	1,000	900.1	10.5		97	12.32	ssw.	4.5	
4:18	1,194	879.5	9.9	0.29	85	10.37	ssw.	4.4	
	1,500	847.6	8.0		93	9.98	sw.	5.7	
4:21	1,742	823.2	6.5	0.62	100	9.68	wsw.	6.0	
4:22	1,898	807.6	6.1	0.26	66	6.21	wsw.	5.8	
	2,000	797.6	6.3		60	5.72	wsw.	5.4	
4:23	2,163	782.0	6.5	−0.15	51	4.94	wsw.	5.0	
	2,500	750.5	5.1		44	3.86	ssw.	4.7	
4:25	2,592	741.9	4.7	0.42	42	3.59	wsw.	4.5	
4:27	2,868	717.3	2.7	0.72	46	3.41			
	3,000	705.7	1.8		44	3.06			
4:32	4,003	622.4	−4.8	0.66	32	1.31			
4:36	4,937	552.3	−11.6	0.73	34	0.77			
	5,000	547.7	−11.8		34	0.76			
4:39	5,622	505.2	−13.8	0.32	30	0.56			
	6,000	479.7	−15.2		29	0.48			
	7,000	420.2	−18.7		28	0.33			
	8,000	367.6	−22.4		26	0.22			
4:44	8,430	347.3	−23.9	0.36	25	0.18			
	9,000	321.0	−26.7		25	0.13			
	10,000	280.3	−31.7		24	0.08			
4:49	10,165	273.5	−32.5	0.50	24	0.07			
4:51	10,528	259.9	−35.3	0.77	25	0.05			
4:52	10,764	251.4	−37.3	0.85	24	0.04			

DECEMBER 17, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
A. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
7:27	233	982.2	13.0		98	14.68	e.	2.7	9 St. Cu., Sw.; 10 light haze.
	500	951.5	12.4		95	13.68	se.	4.8	
7:30	924	904.7	11.4	0.23	91	12.27	sse.	2.5	
	1,000	896.2	11.0		92	12.08	sse.	2.4	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 17, 1929—Continued

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
A. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
7:32	1,399	854.5	9.1	0.49	100	11.56			
	1,500	843.9	8.6		96	10.72			
7:35	1,946	800.0	6.4	0.50	79	7.59			
	2,000	794.3	5.9		80	7.42			
	2,500	747.1	1.9		91	6.37			
7:38	2,702	728.7	0.3	0.80	96	5.99			
	3,000	701.9	−1.3		74	4.06			
7:41	3,391	668.7	−3.4	0.54	46	2.12			
	4,000	618.7	−7.8		44	1.39			
7:47	4,711	564.4	−12.9	0.72	41	0.83			
	5,000	543.7	−14.1		38	0.69			
7:51	5,669	498.1	−17.0	0.43	30	0.42			
	6,000	476.5	−20.7		34	0.33			
7:55	6,656	435.7	−28.0	1.11	41	0.19			
	7,000	415.7	−30.2		42	0.16			
	8,000	361.3	−36.7		45	0.08			
8:01	8,380	342.2	−39.1	0.64	46	0.06			
	9,000	312.9	−43.4		46	0.04			
	10,000	269.9	−50.4		45	0.02			
	11,000	231.9	−57.3		44	0.01			
8:10	11,072	229.3	−57.8	0.69	44	0.01			Tropopause.
	12,000	199.4	−56.8		42	0.01			
	13,000	170.9	−55.8		40	0.01			
	14,000	146.0	−54.7		38	0.01			
8:18	14,019	145.6	−54.7	−0.11	38	0.01			
	15,000	125.1	−56.9		37	0.01			
	16,000	107.3	−59.1		37	(1)			
8:28	16,706	95.9	−60.7	0.22	36	(1)			
	17,000	91.8	−60.3		36	(1)			
	18,000	78.6	−59.0		36	(1)			
8:38	18,962	67.5	−57.8	−0.13	36	(1)			

DECEMBER 18, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:45	233	999.0	−8.4		70	2.11	n.	13.4	6 A. Cu., NW.; 4 St., NNW.
	500	965.0	−10.4				nnw.	16.7	
4:48	903	915.5	−13.4	0.75			nw.	19.1	
	1,000	904.0	−12.9				nw.	18.9	
4:49	1,185	882.3	−12.0	−0.50			nnw.	18.2	
	1,500	846.6	−13.4						
	2,000	792.5	−15.7						
4:53	2,010	791.4	−15.7	0.45					
4:54	2,246	767.2	−16.0	0.13					
	2,500	741.8	−17.3						
	3,000	693.6	−19.9						
4:59	3,249	670.7	−21.2	0.52					
5:00	3,505	647.8	−22.6	0.55					
	4,000	605.5	−24.6						
5:04	4,542	562.0	−26.7	0.40					
	5,000	527.3	−30.3						
5:06	5,071	522.3	−30.9	0.79					
	6,000	457.7	−36.6						
5:12	6,874	403.1	−42.0	0.62					

DECEMBER 19, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100\ m.}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:10	233	996.5	−6.0		45	1.66	nw.	4.9	Cloudless.
	500	962.9	−8.4		47	1.41	nw.	6.6	
4:14	762	930.9	−10.7	0.89	48	1.18	nw.	6.6	
	1,000	902.2	−13.1		51	1.01	nw.	7.2	
4:18	1,464	848.2	−17.8	1.01	56	0.72	nw.	10.1	
	1,500	844.1	−17.6		55	0.72	nw.	10.4	
4:19	1,646	827.9	−17.0	−0.44	50	0.70	nnw.	12.4	
4:20	1,848	806.1	−16.8	−0.10	44	0.62	nnw.	13.2	
	2,000	789.7	−17.2		47	0.64	nnw.	13.6	
4:21	2,157	773.4	−17.6	0.26	51	0.67	nnw.	13.9	
4:23	2,456	743.3	−17.8	0.07	51	0.66	nw.	14.0	
	2,500	738.8	−18.0		51	0.64	nw.	14.3	
	3,000	690.8	−20.1		56	0.58	nw.	18.0	
4:26	3,008	690.2	−20.1	0.42	56	0.58	nw.	18.3	
4:28	3,355	658.6	−20.7	0.17	57	0.56	nw.	21.2	
4:29	3,629	634.5	−20.7	0.00	52	0.51	nw.	20.8	
4:30	3,744	624.5	−21.5	0.70	51	0.46	nw.	24.6	
	4,000	603.3	−21.7		49	0.44	nw.	21.9	
4:35	4,478	565.1	−22.1	0.08	45	0.38	nw.	33.0	
	5,000	526.3	−25.3		43	0.27	nw.	32.2	
4:40	5,624	483.0	−29.1	0.61	40	0.17	nw.	32.5	
	6,000	457.7	−32.4		39	0.12	nw.	32.0	
4:45	6,538	423.4	−37.2	0.89	38	0.07	nw.	31.7	
	7,000	396.8	−39.1		37	0.05	nw.	37.8	
4:49	7,417	374.1	−40.9	0.42	37	0.04	nw.	38.3	
	8,000	343.2	−44.3		37	0.03	nw.	36.0	
4:56	8,990	295.3	−50.1	0.58	37	0.01	nw.	40.6	Tropopause.
5:00	9,993	253.8	−50.1	0.00	36	0.01	nw.	44.6	
	10,000	253.6	−50.1		36	0.01	nw.	44.6	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 19, 1929—Continued

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P.m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
5:01	10,401	238.6	−49.9	−0.05	36	0.01			
	11,000	217.9	−50.5		36	0.01			
5:07	11,806	193.0	−51.3	0.10	36	0.01			
	12,000	187.1	−52.5		36	0.01			
5:14	12,515	172.5	−55.8	0.63	35	0.01			
	13,000	160.3	−55.8		35	0.01			
5:19	13,353	151.8	−55.8	0.00	35	0.01			
5:21	13,766	142.4	−58.3	0.61	35	[1]			
	14,000	137.4	−59.1		35	[1]			
5:25	14,355	130.0	−60.3	0.34	34	[1]			
	15,000	117.6	−60.4		34	[1]			
	16,000	100.7	−60.5		34	[1]			
	17,000	85.9	−60.5		34	[1]			
	18,000	73.3	−60.6		34	[1]			
5:48	18,704	65.3	−60.7	0.01	34	[1]			

DECEMBER 20, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
4:01	233	999.9	1.0		49	3.21	w.	2.0	1 Ci., WSW.
	500	967.0	−1.9		49	2.56	w.	4.9	
4:04	849	925.3	−5.6	1.07	49	1.88	wnw.	5.6	
	1,000	907.6	−7.1		50	1.68	wnw.	6.2	
	1,500	850.6	−12.2		52	1.12	wnw.	7.5	
4:08	1,620	837.5	−13.4	1.01	53	1.02	wnw.	9.4	
	2,000	796.6	−12.9		56	1.13	wnw.	12.2	
4:10	2,034	793.1	−12.9	−0.12	57	1.15	wnw.	12.0	
4:11	2,317	764.2	−13.8	0.32	57	1.06	wnw.	12.0	
4:12	2,479	748.2	−13.3	−0.31	54	1.05	wnw.	12.5	
	2,500	746.1	−13.4		54	1.04	wnw.	12.6	
	3,000	698.5	−16.1		51	0.77	wnw.	12.2	
4:16	3,443	658.3	−18.5	0.54	49	0.59	wnw.	15.1	
4:17	3,676	638.4	−17.3	−0.52	45	0.61	wnw.	16.0	
	4,000	611.1	−18.9		49	0.57	wnw.	9.8	
4:23	4,939	538.1	−23.7	0.51	59	0.43	w.	20.9	
	5,000	533.8	−24.1		59	0.41	w.	21.2	
	6,000	465.0	−30.0		57	0.22	w.	28.0	
4:30	6,478	434.9	−32.8	0.59	56	0.16	w.	38.2	
	7,000	403.7	−36.0		53	0.11	w.	38.5	
	8,000	349.2	−42.2		48	0.05	wsw.	44.8	
4:37	8,652	317.3	−46.2	0.62	45	0.03	wsw.	46.5	Tropopause.
4:38	8,880	306.8	−45.5	−0.31	44	0.03	wsw.	45.9	
	9,000	301.4	−45.7		44	0.03	wsw.	44.8	
	10,000	260.3	−47.1		44	0.02	wsw.	51.6	
	11,000	224.2	−48.6		43	0.02	wsw.	49.3	
	12,000	192.7	−50.1		43	0.02	wsw.	48.0	
4:49	12,087	189.7	−50.7	0.16	43	0.02	wsw.	48.8	
	13,000	165.2	−52.0		43	0.01	w.	42.2	
	14,000	141.7	−53.3		43	0.01	w.	25.6	
	15,000	121.5	−54.7		43	0.01	w.	21.2	
	16,000	104.0	−56.1		43	0.01	w.	28.9	
5:01	16,861	90.7	−57.3	0.14	43	0.01	w.	19.8	
	17,000	88.6	−57.5		43	0.01	w.	18.7	
	18,000	75.8	−59.3		43	[1]	w.	17.3	
5:09	18,927	65.7	−60.9	0.17	43	[1]	w.	7.1	
	19,000	64.8	−60.8		43	[1]	w.	6.8	
	20,000	55.5	−59.1		42	[1]			
5:24	20,355	52.3	−58.5	−0.17	42	0.01			

DECEMBER 21, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
4:26	233	1,004.7	−2.5		52	2.58	n.	3.6	4 Ci., SSW.; 5 Ci. St., SW.
	500	971.2	−4.8		53	2.17	nnw.	6.3	
4:29	873	926.1	−8.1	0.88	55	1.70	nnw.	5.7	
	1,000	911.1	−8.0		53	1.65	nnw.	5.5	
4:30	1,404	864.8	−7.7	−0.08	47	1.50	nnw.	4.7	
	1,500	854.3	−8.1		47	1.45	nnw.	4.9	
	2,000	800.9	−10.1		46	1.20	nnw.	5.8	
4:33	2,391	761.3	−11.6	0.40	45	1.02	nw.	4.7	
	2,500	750.5	−12.2		44	0.95	nw.	4.9	
	3,000	702.7	−14.7		42	0.72	wnw.	7.6	
4:37	3,389	667.4	−16.7	0.50	40	0.57	wnw.	8.9	
	4,000	615.3	−19.5		40	0.44	wnw.	7.4	
4:39	4,184	600.4	−20.3	0.45	40	0.40	w.	7.5	
	5,000	537.5	−23.5		40	0.30	wsw.	16.4	
4:41	5,096	530.4	−23.9	0.39	40	0.29	wsw.	17.7	
	6,000	468.0	−31.2		40	0.14	wsw.	23.7	
4:46	6,613	429.2	−36.1	0.80	40	0.08	sw.	30.2	
	7,000	405.7	−39.9		40	0.05	sw.	29.4	
4:50	7,728	364.8	−47.1	0.90	40	0.02			Tropopause.
4:51	7,999	350.5	−46.3	−0.30	40	0.02			
	9,000	301.7	−49.6		39	0.02			
4:55	9,597	275.7	−51.5	0.32	38	0.01			
	10,000	259.6	−51.0		38	0.01			
4:58	10,705	233.2	−50.1	−0.13	38	0.01			
	11,000	222.7	−50.8		38	0.01			
	12,000	191.5	−53.0		38	0.01			
	13,000	164.0	−55.3		38	0.01			

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 21, 1929—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P.m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
5:06	13,108	161.2	−55.5	0.22	38	0.01			
5:07	13,199	158.8	−54.5	−1.00	38	0.01			
	14,000	140.5	−55.4		38	0.01			
5:10	14,072	138.7	−55.5	0.11	38	0.01			
	15,000	120.0	−60.4		38	[1]			
5:16	15,294	114.5	−62.0	0.53	38	[1]			
	16,000	102.3	−62.3		38	[1]			
5:19	16,334	97.0	−62.5	0.05	38	[1]			

DECEMBER 22, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
3:32	233	998.4	−0.7		44	2.54	n.	3.1	Cloudless.
	500	966.1	−3.5				n.	4.6	
	1,000	904.3	−8.9				n.	6.2	
3:36	1,192	882.2	−10.9	1.06			n.	6.4	
	1,500	848.7	−11.3				nnw.	9.0	
3:38	1,551	841.9	−11.4	0.14			nnw.	9.0	
	2,000	794.5	−13.7				wnw.	10.4	
3:42	2,448	748.2	−16.0	0.51			wnw.	10.6	
	2,500	743.5	−16.3				wnw.	10.4	
	3,000	693.7	−19.5				wnw.	11.3	
3:48	3,883	614.7	−25.1	0.63			wnw.	13.3	
	4,000	605.4	−25.9				wnw.	14.0	
	5,000	526.8	−32.8				wnw.	29.0	
3:55	5,558	484.2	−36.6	0.70			wnw.	35.0	
	6,000	457.3	−38.2				wnw.	34.9	
	7,000	395.8	−41.7				wnw.	42.6	
4:00	7,039	390.2	−41.8	0.35			wnw.	42.6	
	8,000	341.2	−46.8				wnw.	39.6	
	9,000	293.6	−52.1				w.	34.4	
4:10	9,386	273.5	−54.1	0.52			w.	35.0	Tropopause.
	10,000	251.4	−54.0				w.	27.6	
	11,000	215.4	−53.9				w.	36.3	
	12,000	185.3	−53.7				w.	29.5	
4:20	12,066	180.3	−53.7	−0.01			w.	28.0	
	13,000	159.5	−56.0				wsw.	28.2	
	14,000	137.2	−58.4						
	15,000	117.3	−60.9						
4:37	15,780	100.1	−62.8	0.25					

DECEMBER 23, 1929

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
4:12	233	994.4	5.0		48	4.19	sw.	4.9	Cloudless.
	500	962.1	2.9				ssw.	8.0	
	1,000	904.1	−1.0				sw.	7.9	
4:16	1,079	895.2	−1.6	0.78			sw.	7.8	
4:18	1,423	857.3	−2.3	0.20			wsw.	11.7	
	1,500	849.0	−2.6				w.	11.8	
4:20	1,872	809.9	−4.3	0.45			w.	8.4	
	2,000	796.9	−4.3				w.	7.9	
4:21	2,146	782.3	−4.2	−0.04			w.	7.9	
	2,500	747.7	−6.0				wnw.	11.2	
	3,000	701.2	−8.6				nw.	12.9	
4:27	3,313	673.5	−10.2	0.51			nw.	14.5	
	4,000	615.7	−14.4				nw.	16.5	
4:31	4,234	597.0	−15.8	0.61			nw.	16.0	
	5,000	539.5	−18.5				nnw.	23.7	
4:36	5,269	520.2	−19.4	0.35			nnw.	23.0	
	6,000	470.9	−24.7				nnw.	30.7	
4:41	6,634	431.6	−29.3	0.73			nnw.	34.8	
	7,000	410.0	−32.1				n.	35.7	
	8,000	355.5	−39.9				n.	37.1	
4:49	8,729	319.7	−45.5	0.77			nnw.	36.2	
	9,000	306.8	−48.3				nnw.	42.2	
4:56	9,820	271.1	−56.8	1.04			nnw.	43.8	Tropopause.
	10,000	263.8	−56.8				nnw.	42.6	
4:57	10,419	247.0	−56.8	0.00			nnw.	35.9	
	11,000	225.9	−59.8				nnw.	28.7	
5:00	11,176	219.8	−60.7	0.52			nw.	28.5	
5:04	11,822	198.6	−54.0	−1.04			wnw.	24.4	
	12,000	193.4	−54.0				wnw.	19.2	
	13,000	166.4	−54.3				w.	33.3	
	14,000	142.4	−54.5				w.	24.8	
	15,000	122.0	−54.8				w.	27.8	
	15,558	111.6	−54.9	0.02			w.	24.4	
	16,000	104.5	−55.4				w.	24.3	
	17,000	89.7	−56.5				w.	27.3	
	18,000	76.8	−57.7				wnw.	18.4	
	19,000	65.7	−58.8				wnw.	19.5	
	20,000	55.9	−59.9				w.	22.0	
	21,000	47.6	−61.1				w.	22.3	
	21,289	45.5	−61.4	0.11			w.	17.8	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 24, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:04	233	991. 3	11. 8	------	45	6. 23	w.	3. 6	Cloudless.
	500	960. 0	10. 2	------	46	5. 72	w.	6. 2	
4:06	923	912. 2	7. 6	0. 61	48	5. 01	wnw.	8. 4	
	1, 000	903. 7	7. 9	------	48	5. 11	nw.	9. 3	
4:07	1, 063	896. 9	8. 1	−0. 36	48	5. 18	nw.	10. 0	
	1, 500	850. 1	4. 5	------	49	4. 13	nw.	14. 1	
	2, 000	799. 1	0. 3	------	49	3. 06	nw.	15. 7	
4:13	2, 454	754. 8	−3. 5	0. 83	50	2. 29	nw.	14. 2	
	2, 500	750. 6	−3. 8	------	50	2. 23	nw.	14. 3	
	3, 000	704. 4	−7. 2	------	49	1. 64	nw.	17. 3	
	4, 000	618. 8	−13. 9	------	46	0. 85	nw.	22. 6	
4:18	4, 085	611. 9	−14. 5	0. 67	46	0. 80	nw.	24. 4	
4:19	4, 399	586. 9	−15. 2	0. 22	45	0. 74	nw.	27. 4	
	5, 000	541. 8	−18. 8	------	45	0. 53	nw.	28. 7	
4:22	5, 327	518. 8	−20. 8	0. 60	45	0. 44	nnw.	29. 7	
	6, 000	473. 4	−24. 7	------	42	0. 28	nnw.	44. 4	
4:26	6, 457	444. 8	−27. 4	0. 58	40	0. 20	nnw.	45. 1	
4:27	6, 570	438. 0	−27. 8	0. 35	39	0. 19	nnw.	45. 3	
	7, 000	412. 5	−31. 4	------	37	0. 12	n.	50. 7	
4:31	7, 694	374. 0	−37. 3	0. 85	35	0. 06	n.	50. 8	
	8, 000	------	------	------	------	------	nnw.	52. 0	
	9, 000	------	------	------	------	------	nnw.	44. 8	
	10, 000	------	------	------	------	------	nnw.	28. 4	
	10, 609	------	------	------	------	------	wnw.	25. 0	
	11, 000	------	------	------	------	------	wnw.	34. 9	
	12, 000	------	------	------	------	------	wnw.	24. 9	
	13, 000	------	------	------	------	------	wnw.	20. 0	
	13, 070	------	------	------	------	------	wnw.	20. 0	

DECEMBER 25, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
3:49	233	989. 0	16. 6	------	28	5. 29	sw.	6. 7	Cloudless.
	500	958. 2	15. 0	------	31	5. 29	ssw.	12. 3	
	1, 000	903. 0	11. 9	------	37	5. 15	wsw.	16. 5	
3:53	1, 211	880. 4	10. 6	0. 61	39	4. 98	wsw.	17. 5	
3:54	1, 402	860. 7	12. 6	−1. 05	36	5. 25	w.	18. 0	
3:54½	1, 500	850. 6	11. 5	1. 12	35	4. 75	w.	17. 0	
	2, 000	800. 9	8. 9	------	36	4. 10	w.	13. 3	
	2, 500	753. 7	6. 3	------	37	3. 53	w.	13. 1	
3:58	2, 619	743. 0	5. 7	0. 52	37	3. 39	w.	13. 5	
	3, 000	709. 1	2. 8	------	36	2. 69	wnw.	15. 2	
4:02	3, 559	661. 7	−1. 4	0. 76	35	1. 90	nw.	14. 4	
	4, 000	625. 7	−4. 6	------	35	1. 46	wnw.	16. 9	
4:06	4, 528	585. 0	−8. 4	0. 72	35	1. 05	nw.	17. 7	
	5, 000	550. 7	−11. 2	------	36	0. 85	nw.	17. 9	
4:08	5, 158	539. 4	−12. 1	0. 59	36	0. 78	wnw.	18. 7	
	6, 000	482. 6	−18. 0	------	24	0. 30	nw.	19. 5	
4:13	6, 186	470. 9	−19. 3	0. 70	21	0. 24	nw.	19. 4	
	7, 000	421. 9	−25. 0	------	21	0. 13	nw.	19. 9	
4:16	7, 165	412. 5	−26. 2	0. 70	21	0. 12	nw.	20. 7	
	8, 000	367. 2	−33. 7	------	21	0. 05	nw.	24. 1	
4:21	8, 427	345. 5	−37. 6	0. 90	21	0. 04	nw.	23. 6	
4:23	8, 893	323. 6	−40. 8	0. 69	21	0. 02	wnw.	23. 7	
	9, 000	318. 4	−41. 5	------	21	0. 02	nw.	23. 8	
4:24	9, 235	307. 8	−43. 1	0. 67	20	0. 02	nw.	26. 3	
	10, 000	274. 8	−48. 5	------	20	0. 01	nw.	25. 1	
	11, 000	236. 4	−55. 6	------	20	([1])	nw.	21. 6	
4:31	11, 564	216. 9	−59. 6	0. 71	20	([1])	nw.	24. 7	
	12, 000	202. 8	−62. 4	------	20	([1])	nw.	21. 6	Tropopause.
4:34	12, 212	196. 1	−63. 8	0. 65	20	([1])	nw.	23. 1	
	13, 000	173. 4	−59. 7	------	20	([1])	nw.	21. 3	
4:38	13, 204	168. 0	−58. 7	−0. 51	20	([1])	wnw.	20. 0	
4:39	13, 444	161. 6	−58. 4	−0. 12	20	([1])	wnw.	23. 1	
4:40	13, 706	155. 3	−58. 7	0. 11	20	([1])	nw.	26. 4	
	14, 000	148. 2	−59. 3	------	20	([1])	nw.	26. 7	
4:42	14, 409	139. 2	−60. 1	0. 20	20	([1])	nw.	23. 9	
4:44	14, 642	133. 9	−60. 5	0. 17	19	([1])	nw.	24. 8	
	15, 000	126. 9	−59. 9	------	19	([1])	nw.	18. 5	
4:45	15, 036	126. 2	−59. 8	−0. 18	19	([1])	nw.	18. 2	
	16, 000	108. 5	−61. 4	------	19	([1])	wnw.	16. 4	
	17, 000	92. 4	−63. 2	------	19	([1])	w.	11. 0	
4:53	17, 087	91. 0	−63. 3	0. 17	19	([1])	w.	12. 4	
	18, 000	78. 9	−62. 7	------	18	([1])	wnw.	8. 5	
5:01	18, 866	68. 7	−62. 1	−0. 07	18	([1])	wnw.	12. 0	
	19, 000	67. 2	−61. 9	------	18	([1])	wnw.	12. 1	
	20, 000	57. 5	−60. 2	------	18	([1])	wnw.	10. 9	
5:10	20, 988	49. 2	−58. 6	−0. 16	18	([1])	w.	6. 4	
	21, 000	49. 1	−58. 6	------	18	([1])	w.	6. 4	
	22, 000	42. 1	−56. 7	------	18	([1])	------	------	
5:17	22, 921	36. 4	−54. 9	−0. 19	18	([1])	------	------	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 27, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:21	233	992. 3	9. 4	------	49	5. 78	n.	3. 8	Cloudless.
	500	960. 6	7. 3	------	47	4. 80	nnw.	6. 0	
4:24	896	915. 3	4. 3	0. 77	45	3. 74	nnw.	8. 9	
	1, 000	903. 7	4. 2	------	44	3. 63	n.	10. 0	
4:25	1, 195	882. 3	4. 1	0. 07	41	3. 36	n.	10. 4	
	1, 500	849. 6	2. 7	------	41	3. 04	nnw.	9. 8	
	2, 000	798. 6	0. 5	------	40	2. 53	nw.	11. 0	
	2, 500	750. 2	−1. 7	------	39	2. 07	nw.	10. 2	
4:31	2, 623	738. 6	−2. 3	0. 04	39	1. 97	nw.	9. 9	
4:33	2, 928	710. 9	−3. 2	0. 30	39	1. 83	wnw.	10. 5	
	3, 000	704. 1	−3. 7	------	39	1. 76	wnw.	10. 9	
	4, 000	614. 4	−10. 5	------	41	1. 03	wnw.	14. 7	
4:38	4, 154	601. 2	−11. 5	0. 68	41	0. 94	wnw.	15. 4	
	5, 000	541. 7	−18. 1	------	38	0. 48	wnw.	11. 3	
4:43	5, 267	521. 4	−20. 2	0. 78	37	0. 38	wnw.	10. 5	
4:45	5, 790	489. 0	−21. 7	0. 29	39	0. 35	wnw.	14. 8	
	6, 000	475. 1	−23. 2	------	38	0. 29	wnw.	16. 0	
	7, 000	414. 0	−30. 5	------	36	0. 13	nw.	20. 2	
4:52	7, 451	388. 4	−33. 8	0. 73	35	0. 09	nw.	22. 8	
	8, 000	359. 4	−38. 2	------	36	0. 06	wnw.	25. 2	
	9, 000	310. 4	−46. 2	------	38	0. 02	w.	26. 9	
5:00	9, 660	281. 4	−51. 5	0. 80	39	0. 01	w.	27. 9	Tropopause.
	10, 000	267. 8	−51. 7	------	39	0. 01	w.	33. 1	
	11, 000	230. 6	−52. 2	------	39	0. 01	w.	36. 9	
	12, 000	197. 9	−52. 8	------	39	0. 01	w.	33. 3	
5:09	12, 805	174. 6	−53. 2	0. 05	39	0. 01	w.	35. 8	
	13, 000	169. 7	−53. 6	------	------	------	wsw.	36. 0	
	14, 000	145. 6	−55. 7	------	------	------	w.	33. 7	
	15, 000	124. 4	−57. 8	------	------	------	w.	28. 8	
5:17	15, 938	107. 4	−59. 8	0. 21	------	------	w.	27. 6	
	16, 000	106. 2	−60. 0	------	------	------	w.	27. 3	
	17, 000	90. 7	−63. 7	------	------	------	wsw.	21. 0	
	18, 000	77. 3	−67. 4	------	------	------	w.	15. 0	
	19, 000	65. 5	−71. 0	------	------	------	------	------	
5:29	19, 078	64. 8	−71. 3	0. 37	------	------	------	------	

DECEMBER 28, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	Δt / 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:22	233	995. 6	9. 8	------	32	3. 88	n.	6. 7	Cloudless.
	500	964. 0	7. 9	------	32	3. 41	n.	10. 4	
4:26	935	914. 1	4. 8	0. 71	32	2. 75	nnw.	10. 2	
	1, 000	907. 0	4. 3	------	32	2. 66	nnw.	10. 4	
	1, 500	852. 4	0. 4	------	30	2. 58	nw.	15. 0	
4:29	1, 596	842. 3	−0. 4	0. 79	30	1. 77	nw.	16. 2	
4:30	1, 759	825. 3	−1. 3	0. 55	25	1. 37	nw.	17. 2	
	2, 000	800. 7	−2. 8	------	26	1. 26	nw.	19. 3	
	2, 500	751. 6	−5. 9	------	30	1. 12	nw.	26. 2	
4:35	2, 906	713. 4	−8. 4	0. 62	32	0. 96	nw.	28. 5	
	3, 000	704. 8	−8. 4	------	32	0. 96	nw.	30. 0	
4:38	3, 386	670. 7	−8. 4	0. 00	34	1. 02	nw.	33. 5	
	4, 000	620. 5	−14. 0	------	37	0. 68	nw.	39. 1	
4:42	4, 096	613. 2	−14. 9	0. 92	37	0. 63	nw.	37. 8	
4:44	4, 376	591. 5	−13. 6	−0. 46	34	0. 65	wnw.	34. 4	
	5, 000	544. 5	−18. 6	------	34	0. 40	nw.	33. 4	
4:50	5, 831	486. 6	−25. 3	0. 80	35	0. 22	wnw.	33. 8	
	6, 000	475. 5	−26. 6	------	35	0. 19	wnw.	34. 0	
	7, 000	413. 5	−34. 5	------	35	0. 08	wnw.	35. 0	
4:55	7, 222	400. 7	−36. 2	0. 78	35	0. 07	wnw.	39. 2	
4:56	7, 430	388. 8	−37. 3	0. 53	33	0. 06	wnw.	41. 2	
	8, 000	358. 2	−41. 0	------	32	0. 04	wnw.	40. 8	
5:01	8, 480	334. 1	−44. 2	0. 66	32	0. 02	w.	46. 3	
5:02	8, 600	328. 0	−43. 3	−0. 75	32	0. 03	w.	48. 0	
	9, 000	309. 5	−46. 5	------	31	0. 02	w.	47. 8	
5:07	9, 807	274. 2	−53. 0	0. 80	28	0. 01	w.	53. 9	Tropopause.
	10, 000	266. 4	−52. 2	------	30	0. 01	w.	47. 4	
5:08	10, 183	259. 2	−51. 4	−0. 43	32	0. 01	w.	49. 0	
	11, 000	228. 8	−54. 4	------	31	0. 01	w.	51. 0	
5:13	11, 425	214. 4	−55. 9	0. 36	30	0. 01	w.	37. 5	
	12, 000	196. 5	−55. 7	------	27	0. 01	w.	41. 2	
	13, 000	168. 2	−55. 5	------	22	([1])	------	------	
5:20	13, 320	159. 9	−55. 4	−0. 26	21	([1])	------	------	
5:23	13, 772	149. 2	−58. 0	0. 58	21	([1])	------	------	
	14, 000	143. 9	−58. 0	------	21	([1])	------	------	
	15, 000	123. 0	−57. 7	------	21	([1])	------	------	
5:30	15, 141	120. 3	−57. 7	−0. 22	21	([1])	------	------	
	16, 000	105. 2	−60. 6	------	21	([1])	------	------	
5:35	16, 521	96. 9	−62. 3	0. 33	21	([1])	------	------	
	17, 000	89. 8	−62. 0	------	------	------	------	------	
	18, 000	76. 7	−61. 0	------	------	------	------	------	
5:51	18, 519	70. 7	−60. 6	−0. 85	------	------	------	------	

[1] Less than 0. 01 mb.

Table 2.—*Tabulated data of sounding-balloon ascents made at Broken Arrow, Okla., during December, 1929*—Continued

DECEMBER 29, 1929

Time 90th mer.	Altitude (M. S. L.)	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	° *C.*		*P. ct.*	*Mb.*		*M.p.s.*	
3:44	233	991.9	16.6	-------	32	6.05	sw.	5.8	Cloudless.
	500	961.1	14.6	-------	32	5.32	wsw.	8.6	
3:47	928	913.3	11.5	0.73	32	4.34	wsw.	10.6	
	1,000	905.4	11.0	-------	32	4.20	wsw.	11.3	
3:49	1,490	853.5	7.8	0.66	32	3.39	w.	19.0	
	1,500	852.5	7.8	-------	32	3.39	w.	19.0	
	2,000	802.3	6.9	-------	30	2.98	wnw.	17.5	
3:52	2,122	790.4	6.7	0.17	30	2.94	wnw.	16.9	
	2,500	754.7	4.9	-------	31	2.68	wnw.	16.2	
	3,000	709.7	2.4	-------	32	2.32	nw.	14.1	
3:59	3,711	649.9	−1.0	0.48	34	1.91	nw.	17.0	
	4,000	626.7	−2.5	-------	34	1.69	nw.	19.3	
	5,000	551.9	−7.7	-------	35	1.12	wnw.	20.8	
4:04	5,025	550.2	−7.8	0.52	35	1.11	wnw.	20.8	
	6,000	484.3	−16.2	-------	32	0.48	nw.	18.8	
4:11	6,626	446.0	−21.6	0.86	30	0.27	nnw.	23.2	
	7,000	423.8	−25.0	-------	30	0.19	nnw.	25.0	
4:15	7,728	383.1	−31.8	0.93	30	0.10	nw.	22.5	
	8,000	369.0	−33.7	-------	30	0.08	nw.	21.2	
	9,000	320.1	−40.9	-------	29	0.03	n.	26.6	
4:22	9,686	289.7	−45.8	0.66	28	0.02	n.	30.0	Tropopause.
	10,000	276.3	−45.9	-------	28	0.02	nnw.	23.1	
4:24	10,339	262.8	−46.0	0.03	28	0.02	nw.	19.8	
	11,000	238.5	−48.0	-------	27	0.01	nw.	29.6	
	12,000	205.5	−50.9	-------	26	0.01	nw.	34.6	
4:31	12,828	181.0	−53.4	0.30	25	0.01	nnw.	20.1	
	13,000	176.5	−54.0	-------	25	0.01	nnw.	23.6	
	14,000	151.4	−57.5	-------	25	(1)	nw.	20.2	
	15,000	129.5	−61.1	-------	25	(1)	nw.	20.0	
4:42	15,738	115.4	−63.7	0.35	25	(1)	nnw.	17.6	
	16,000	110.7	−63.8	-------	25	(1)	nnw.	13.3	
	17,000	94.4	−64.0	-------	25	(1)	nnw.	11.8	
4:50	17,555	86.4	−64.1	0.02	25	(1)	nnw.	14.6	
	18,000	80.5	−63.4	-------	25	(1)	nnw.	14.4	
4:54	18,550	73.6	−62.6	−0.15	25	(1)	nw.	20.2	

[1] Less than 0.01 mb.

LITERATURE CITED

(1) Annals Harvard College Observatory, Vol. 68, Pt. 1
(2) Monthly Weather Review, June 1929, pp. 231–246.
(3) Monthly Weather Review, July 1927, pp. 293–307.

WIND VELOCITIES AT DIFFERENT HEIGHTS ABOVE GROUND

By C. F. Marvin

A correspondent inquires whether the Weather Bureau has made any investigations to determine the relative wind velocity as indicated by an anemometer at different heights above ground. The following reply was made:

Replying to your telegram of August 21, requesting information as to velocities indicated by anemometers at different heights above the ground, you are advised that the Weather Bureau has conducted a number of inconclusive comparisons of wind velocities measured at its stations at different elevations, with the hope that some rational rule would result for coordinating the indications at various heights. Thus far, however, we have not felt justified in announcing any such coordination or formula, so to speak, for reduction to uniform elevations.

The demands upon the bureau for service to the public in great metropolitan and other city areas compel us to occupy quarters such as can be procured in these cities. It is recognized that the wind-velocity records obtained under these conditions are not entirely satisfactory. If one contemplates the skyline of the modern great city, it is obvious that the flow of air over the house tops and among the skyscrapers is turbulent and difficult to measure with any specially significant result. On the other hand, observations made in the open country or in cities of moderate population necessarily represent only those localities, and can not, with assurance, be applied to other localities. Our policy, therefore, has been to submit records as obtained, without attempting to modify or adjust these records, and to supply to any interested person a complete description of the environment and nature of exposure of the anemometer at the particular station, leaving it to the user of the records to make such correlations with environment as may seem to him to be best.

Apart from the foregoing, you are further advised that various comparative observations have been made for winds at different altitudes over an open plain or country, and one formula for increase of velocity is approximately

$$V = V_o \left(\frac{h}{h_o}\right)^{\frac{1}{5}}$$

where h is the height in meters above the surface for which the velocity V in meters per second is to be computed, and h_o the known height (not less than 16 meters) at which the velocity V_o is measured. There are still other relations that cover the general increase in velocity upward for much greater elevations. I infer, however, that you are interested only in elevations of several hundred feet above the actual surface.

THE WEATHER AND RADIO

By W. J. Humphreys

It appears to be human nature to explain whatsoever is not understood by attributing it to something that is still more mysterious, or even to the supernatural. At any rate this is a very common human practice, as excellently illustrated by the many appeals that have come to the Weather Bureau to have radio broadcasting suppressed, on the ground that it is burning up the water vapor of the air and thereby, or in some other manner, greatly decreasing the amount of rainfall, and thus causing disastrous droughts.

On the other hand, some who were bothered with more rain than needed were equally insistent that radio is the cause of excessive precipitation and floods, and urged that therefore all wireless communication be forthwith and preemptorily forbidden.

Let us analyze somewhat nature's way of making rain, and from that see, if we can, just how and to what extent radio does affect precipitation.

1. The first action necessary to precipitation is evaporation, by which water in the gaseous form is gotten into and made a portion of the atmosphere. Now the chief factors that affect the rate of evaporation are: (*a*) Temperature of the evaporating water; (*b*) area of the evaporating surface; (*c*) wind velocity; (*d*) dryness of the air. Of course no one in the neighborhood of a powerful "sending station" ever claims that any lake, reservoir or other body of water near-by, spreads over a lot more ground when the station is in operation than it does when the station is silent. He knows, too, that the temperature of the water does not appreciably vary, if at all, with the wireless activity. Neither, so far as any one can observe, does the wind round about a wireless station change with the amount of its broadcasting or receiving. We shall see presently, too, that radio does not alter the dryness of the air.

Obviously, since radio does not affect any of the things that themselves make for evaporation, neither does it affect evaporation itself.

2. The next step by nature in producing rain is to condense the water vapor out of the air in the form of drops. To this end two things are necessary: (*a*) One of these is the presence of condensation nuclei, that is, excessively small particles of sea salt, certain kinds of land dust, or other substances that readily take up water vapor. These nuclei about which cloud droplets form always are in the atmosphere in superabundance. Besides, they are not produced by wireless waves, as we know by direct experiment. (*b*) The other essential to

get the water vapor condensed is an adequate cooling of the vapor, and with it (unavoidably) the other elements of the atmosphere. But the temperature of the air does not go down about an active wireless station any more rapidly, nor to a lower degree, than it does at other similarly located places.

Evidently, then, radio does not take water vapor out of the air and make it drier, thus increasing evaporation and subsequent rainfall. Neither does it prevent or decrease rainfall since it has no effect on any of the factors of either evaporation or condensation.

Again, drought may prevail in one region at the same time that another, with equal wireless facilities, is being flooded. Furthermore, droughts and floods, such as we now have, prevailed time and again throughout the world long before wireless was ever dreamed of.

Finally, from purely theoretical considerations, we know that the relatively small amount of energy used in broadcasting is not sufficient by millions of fold to produce any appreciable change in the amount of precipitation over either the United States as a whole, or even any one of its units.

However much radio may be affected by the weather, especially by the thunderstorm, no element of the weather is affected in turn by radio. We know this from experiment and observation, and we know it from theory as well.

AN ERROR IN THE MAXIMUM-THERMOMETER READING

By W. J. HUMPHREYS

In the case of the mercurial maximum thermometer that breaks its column at a point of constriction the reading always is too low if made after appreciable cooling. This is well known, but perhaps not as generally recognized and fully understood as it might be.

Let

V_m = the stem volume between consecutive degree marks at the time of maximum temperature.

V_t = the stem volume between consecutive degree marks when the temperature is t.

t_o = the stem reading at the point of break of column.

t = the temperature at time of reading.

t_m = the true maximum temperature.

t'_m = the maximum temperature as read.

M = the coefficient of the *volume* expansion of mercury.

G = the coefficient of the *volume* expansion of the thermometer stem—threefold the coefficient of its linear expansion.

The volume of the mercury column at the time of maximum temperature, is, of course, the volume of that portion of the stem then filled. That is, at the temperature t_m

$$\text{Volume of mercury} = \text{volume of glass} = V_m(t_m - t_o)$$

At the time of reading, however, or when the mercury has cooled from t_m to t, the volume of this same mass of mercury is

$$V_m(t_m - t_o) - MV_m(t_m - t_o)(t_m - t), \text{ or } V_m(t_m - t_o)\{1 - M(t_m - t)\}$$

while the original occupied stem volume has become

$$V_m(t_m - t_o)\{1 - G(t_m - t)\}$$

Hence the apparent or virtual shrinkage of the mercury, being the difference between the true shrinkage of the mercury and the true shrinkage of the glass, is

$$V_m(t_m - t_o)(M - G)(t_m - t)$$

Now the error of the reading evidently is the number of the unit stem volumes (volume between consecutive degree marks) whose total volume at the time of observation, when the temperature is t, is equal to the virtual shrinkage of the mercury since the temperature was t_m. Let this number be x, then

$$\begin{aligned} xV_t &= V_m(t_m - t_o)(M - G)(t_m - t) \\ &= V_m(t'_m + x - t_o)(M - G)(t'_m + x - t) \end{aligned}$$

From this equation the numerical value of x, the error in question in degrees, could be computed if we knew the ratio of V_m to V_t, since the values of all the other terms are known. Clearly,

$$V_t = V_m\{1 - G(t'_m + x - t)\}$$

But since G is very small, 0.000025, about, per degree centigrade, and $t_m - t$ seldom large, say, 20° C. at most, it follows that no observable error will be made by assuming V_t and V_m to be exactly equal to each other. With this assumption the value of x is readily computed.

To simplify, let

$$\begin{aligned} M - G &= d \\ t'_m - t_o &= a \\ t'_m - t &= b \end{aligned}$$

Then

$$x = (a + x)d(b + x)$$

Finally, since x is very small in comparison with either a or b, we can, without measureable error, write

$$\begin{aligned} x &= adb \\ &= (t'_m - t_o)\ (M - G)\ (t'_m - t) \end{aligned}$$

the form in which the value of this error commonly is expressed.

In practice this error, or value of x, seldom amounts to more than 0.1° F. or 0.2° F., and therefore for most purposes is negligible. It might be sufficient, however, to change a Weather Bureau's telegraphed value by 2°. Thus, suppose the reading taken just after maximum, is 91°+, F., and the reading some time later, following considerable cooling, 91°−, F. Owing to code exigencies the first would be reported as 92° F., and the second as 90° F. Fortunately, though, even this occasional error is of little importance, since it is the permanent station record of actual readings and not the ephemeral telegraphed report that are considered in climatological and kindred studies.

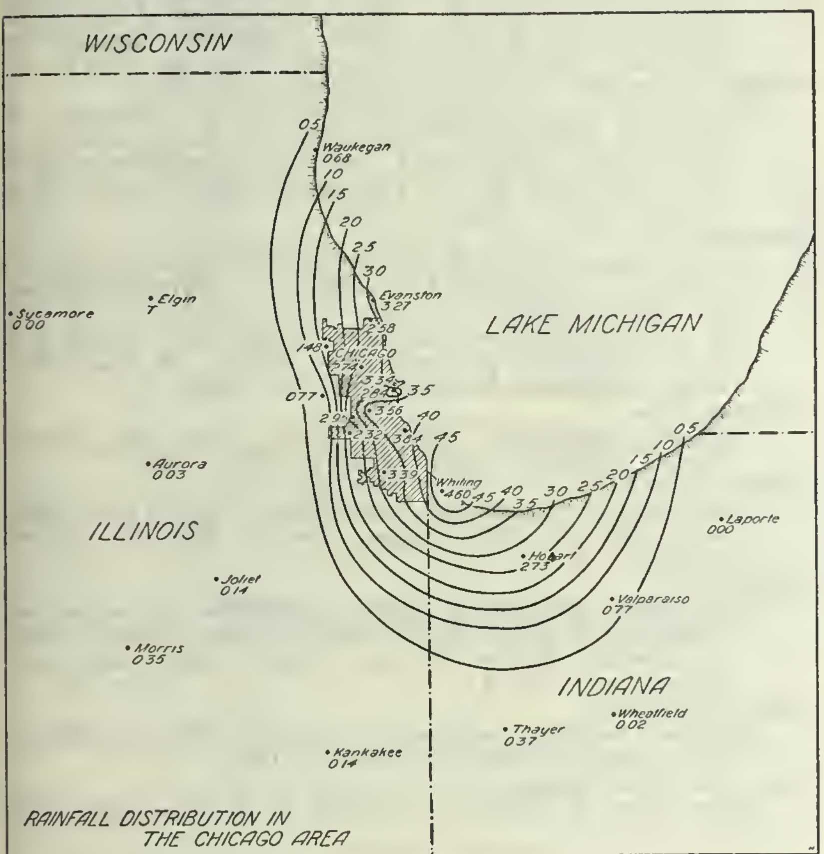
In short this particular error of the maximum thermometer is of little to no importance in meteorology. Nevertheless, it is pleasant to know that there is such an error and reassuring to understand clearly when and why it may be ignored.

A REMARKABLY HEAVY RAINSTORM IN THE CHICAGO AREA

By O. T. Lay

[Weather Bureau Office, Chicago, Ill., September 10, 1931]

On the night of August 10–11, 1931, a remarkably heavy rainstorm occurred in the Chicago area. The total amount of rainfall at the main observatory of the Weather Bureau, on the campus of the University of Chicago, during a period of slightly more than 10 hours, beginning at 8:47 p. m. on the 10th, was the heaviest of record since 1885, and among the heaviest for the entire 61 years of record. The totals of 1.22 inches within 15 minutes and 1.39 inches within 20 minutes broke all previous records for similar periods. Basements and subways in much of the city were flooded, and other damage resulted from the rain and accompanying wind.



RAINFALL DISTRIBUTION IN THE CHICAGO AREA

The rainfall was heaviest along the lake front in and immediately to the southeast of the city, the greatest totals being 4.60 inches at Whiting, Ind., and 3.84 inches at the Weather Bureau observatory at the University of Chicago. Amounts decreased rapidly at stations in all directions from an area including these two points. At Laporte, Ind., 40 miles to the east of Whiting, and Sycamore, Ill., 50 miles to the west of the city limits of Chicago, no rain whatever occurred.

The wind varied from northeast to northwest, and the rainfall was heaviest along those parts of the lake front that received the most direct "lake" wind. There was no general storm area in the region, and the barometer was either stationary or rising slowly during the storm. The temperature at Chicago fell from about 70° at the beginning of the storm to 56° at midnight on the 10th, when one of the heavy downpours occurred, rose slightly for some time thereafter, then fell again to 57° in the early morning of the 11th, when another very heavy downpour occurred. Apparently an inflow of comparatively cold air aloft from over the lake was responsible to a considerable extent for the rapid condensation from moist air over the land area adjacent to those portions of the lake from which the cold air approached.

The accompanying chart shows the distribution of rainfall as measured at stations of the Weather Bureau, the Sanitary District, and the Bureau of Water Safety Control of the City of Chicago.

80390—31——2

MORE RAIN IN DROUGHT YEAR [1]

Missouri has advanced thus far through the crop season with a total rainfall comparable in many ways with the rainfall of 1930, the great drought year. And as with Missouri, so with many of the States of the central crop area.

Last year the shortage caused famine conditions in many sections; this year crops, generally, are fair to good to excellent. Up to July 1 in Missouri the 1931 rainfall just about balanced that of last year, with the advantage, slight as it was, with the drought year. In 1930 Missouri rainfall up to and including June was 82 per cent of normal and this year it was only 81 per cent of normal.

The difference was that the 1930 rains came in unusual quantities in January and February and the four months to follow were unusually dry. This year, the first two months of the year were very dry and general, though light, rains fell during the four months that followed. The distribution, according to season, was better this year than last and the advantage was shown in the crop variations of the two years. But in 1930 the July rain was only 24 per cent of normal, while this year the percentage was 81, with considerable damage to corn at a critical period.

Besides supplying crops with needed moisture, the 1931 rains had the great duty of renewing the lakes and ponds and streams and providing subsurface storage for later needs, a duty that has been performed with fair devotion, though many streams remain at low stage, which adds importance to the rather general rains that have been falling up to this time in August. It looks as if Missouri and other States will start the fall and winter with the effects of the great drought of 1930 fully subdued. Surface water that has not flowed into the streams and thus to the seas has been taken up by famished earth many feet below the surface. We have been storing for future crops.

[1] Reprinted from Globe Democrat, St. Louis, Mo., Aug.. 21, 1931.

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING AUGUST, 1931

By HERBERT H. KIMBALL, In Charge Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities at Washington averaged below the normal values for August, and that at Madison and Lincoln they were above the normal.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at Lincoln and Chicago, close to the August average at Madison, New York, and Fresno, and a deficiency at Washington, Pittsburgh, Twin Falls, and La Jolla.

Skylight polarization measurements made on 2 days at Washington gave 54 for the percentage of polarization, which is slightly below the August average. At Madison, polarization measurements made on 6 days give a mean of 62 per cent with a maximum of 70 per cent on the 11th, which are close to the corresponding averages for Madison in August.

A CHANGE IN WEEKLY AVERAGES FOR DAILY TOTALS OF SOLAR RADIATION AT FRESNO, CALIF.

Difficulty was experienced in standardizing the Moll pyrheliometer recording on an Engelhard microammeter at the time it was installed at Fresno, Calif., in October, 1928. In July, 1931, this pyrheilometer was received back at the central office in Washington, exposed beside an Eppley thermoelectric pyrheliometer, and the records from the two compared. The results show that the reduction factor determined at Fresno in 1928 was too high, the ratio of the new to the old factor being 0.94. Therefore, all pyrheliometer records for Fresno, Calif., obtained previous to July 23, 1931, the date when a new instrument was installed, should be multiplied by 0.94. Weekly means for Fresno heretofore in use have been so reduced.

TABLE 1.—*Solar radiation intensities during August, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m. — 75th mer. time — e.	78.7° — Air mass A. M. 5.0	75.7° — A. M. 4.0	70.7° — A. M. 3.0	60.0° — A. M. 2.0	0.0° — [1]1.0	60.0° — P. M. 2.0	70.7° — P. M. 3.0	75.7° — P. M. 4.0	78.7° — P. M. 5.0	Noon — Local mean solar time — e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Aug. 6	19.23	------	------	0.51	0.77	------	------	------	------	------	15.11
Aug. 7	17.37	------	0.51	0.64	0.87	------	------	------	------	------	15.11
Aug. 17	15.65	------	------	0.67	0.89	1.21	------	------	------	------	11.81
Aug. 24	10.97	------	------	------	1.11	1.36	------	------	------	------	10.59
Aug. 31	14.10	------	0.50	0.68	0.92	1.39	------	------	------	------	12.24
Means	------	------	(0.50)	0.62	0.91	1.32	------	------	------	------	------
Departures	------	------	−0.16	−0.13	−0.01	+0.10	------	------	------	------	------

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Aug. 3	11.81	------	0.79	------	------	------	------	------	------	------	12.68
Aug. 4	15.11	------	------	------	------	1.25	------	------	------	------	12.24
Aug. 5	14.60	------	------	------	0.97	------	------	------	------	------	14.10
Aug. 6	18.59	------	0.50	0.55	0.82	------	------	------	------	------	15.11
Aug. 10	10.21	------	------	------	1.19	------	------	------	------	------	9.83
Aug. 11	8.81	0.80	0.88	1.01	1.21	1.46	1.21	------	------	------	7.29
Aug. 13	10.21	------	------	0.96	1.17	1.35	------	------	------	------	6.50
Aug. 21	8.81	------	0.90	1.07	1.20	1.40	1.13	------	------	------	7.29
Aug. 28	10.59	------	------	1.08	1.17	------	------	------	------	------	7.87
Aug. 29	7.04	------	------	1.08	1.22	1.42	------	------	------	------	6.02
Means	------	(0.80)	0.77	0.96	1.12	1.38	(1.17)	------	------	------	------
Departures	------	+0.05	−0.06	+0.03	+0.03	+0.07	+0.10	------	------	------	------

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Aug. 3	14.10	0.71	0.84	0.96	1.13	1.34	1.13	0.93	0.79	0.65	15.11
Aug. 4	16.79	------	0.82	0.93	1.09	------	------	------	------	------	14.60
Aug. 10	9.83	0.86	0.99	1.12	1.25	1.41	------	------	------	------	9.14
Aug. 11	9.83	------	------	------	1.26	1.46	------	------	------	------	12.68
Aug. 19	13.13	------	------	------	------	------	1.09	0.90	0.75	0.65	15.65
Aug. 22	10.21	------	0.74	0.89	1.07	1.30	1.08	0.89	------	------	11.38
Aug. 28	7.04	------	------	------	------	------	1.17	------	------	------	6.27
Means	------	(0.78)	(0.85)	0.98	1.16	1.38	1.12	0.91	(0.77)	(0.65)	------
Departures	------	+0.11	+0.07	+0.08	+0 08	+0.08	+0.05	+0.02	+0.02	−0.04	------

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

AVERAGE DAILY TOTALS

1931	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 30	460	461	526	422	386	514	462	----	661	360	633	347
Aug. 6	410	447	468	340	283	528	336	----	614	305	573	431
Aug. 13	423	465	549	372	315	464	397	530	637	296	530	298
Aug. 20	265	455	534	408	309	513	275	424	597	401	570	269
Aug. 27	392	390	495	300	378	498	322	435	468	287	528	367

DEPARTURES FROM WEEKLY NORMALS

1931	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
July 30	+5	−2	+4	+52	+18	−86	−7	----	+29	−32	----	----
Aug. 6	−25	−12	−22	−16	−63	−69	−66	----	−87	−59	----	----
Aug. 13	−5	+23	+60	+10	−9	−32	+48	+43	+41	−89	----	----
Aug. 20	−139	+19	+41	+45	−1	−64	−28	−43	+29	−13	----	----
Aug. 27	−23	−17	+38	−44	+65	−56	+20	+12	−74	−110	----	----
Accumulated departures on Sept. 2, 1931	−44	+3,115	+770	−840	−1,190	−3,212	−2,094	----	−140	−6993	----	----

POSITIONS AND AREAS OF SUN-SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column.]

Date	Eastern standard civil time		Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1931	h	m	°	°	°			
Aug. 1 (Naval Observatory)	10	56	+ 2.0	78.2	+7.5	------	46	------
			+9.0	85.2	−6.5	------	62	108
Aug. 2 (Perkins Observatory)	10	37	−50.0	13.1	+3.0	------	117	------
			−3.0	60.1	+20.0	------	93	------
			+9.0	72.1	+23.0	------	70	------
			+17.5	80.6	+4.5	40	------	------
			+19.5	82.1	+20.0	------	62	382
Aug. 3 (Naval Observatory)	10	39	−38.0	11.9	+4.0	------	31	------
			+22.0	71.9	−9.0	------	93	------
			+27.0	76.9	+8.0	------	46	------
			+39.0	88.9	−7.5	6	------	------
			+55.0	104.9	−18.0	6	------	182
Aug. 4 (Naval Observatory)	10	37	−26.0	10.7	+5.0	31	------	------
			+2.0	38.7	−18.0	3	------	------
			+37.0	73.7	−10.0	------	62	------
			+45.0	81.7	+7.0	12	------	------
			+50.0	86.7	−7.5	6	------	114
Aug. 5 (Naval Observatory)	11	18	+50.5	73.6	−9.5	------	93	93
Aug. 6 (Naval Observatory)	10	41	−62.0	308.2	−7.0	------	31	------
			+3.0	13.2	+10.5	9	------	------
			+62.0	72.2	−9.5	------	62	102
Aug. 7 (Naval Observatory	10	41	+79.0	76.0	−10.0	------	62	62
Aug. 8 (Naval Observatory)	10	37	+58.0	41.8	−22.0	6	------	6
Aug. 9 (Naval Observatory)	10	35		No spots				
Aug. 10 (Naval Observatory)	10	43		No spots				
Aug. 11 (Mount Wilson)	18	20	+44.0	343.9	+3.0	5	------	5
Aug. 12 (Yerkes Observatory)	15	6		No spots				
Aug. 13 (Naval Observatory)	12	38		No spots				
Aug. 14 (Mount Wilson)	17	0		No spots				
Aug. 15 (Naval Observatory)	12	2	−62.0	188.5	+10.0	9	------	------
			−49.5	201.0	−19.0	6	------	------
			−36.0	214.5	−8.0	6	------	21
Aug. 16 (Naval Observatory)	10	44	+1.0	239.0	−11.5	9	------	9
Aug. 17 (Naval Observatory)	10	44	+15.0	239.8	−11.0	------	93	93
Aug. 18 (Naval Observatory)	10	44	+28.5	240.0	−10.5	------	93	93
Aug. 19 (Yerkes Observatory)	14	20	+41.6	237.9	−10.6	21	------	------
			+42.9	239.2	−10.2	2	------	------
			+46.3	242.7	−9.6	6	------	------
			+47.4	243.8	−10.1	6	------	------
			+48.6	244.9	−9.6	3	------	------
			+49.2	245.5	−10.8	12	------	50
Aug. 20 (Yerkes Observatory)	12	55	+53.8	237.7	−10.5	20	------	------
			+54.9	238.8	−11.1	------	14	------
			+55.0	238.9	−10.3	6	------	------
			+63.0	246.9	−9.9	18	------	58
Aug. 21 (Yerkes Observatory)	10	33	+66.1	238.1	−10.9	7	------	------
			+66.9	238.9	−11.5	21	------	------
			+67.1	239.1	−10.6	5	------	------
			+75.7	247.7	−9.5	34	------	67
Aug. 22 (Perkins Observatory)	12	25		No spots				
Aug. 23 (Perkins Observatory	10	55		No spots				
Aug. 24 (Naval Observatory)	10	45		No spots			------	------
Aug. 25 (Naval Observatory)	10	40	−24.5	94.6	+3.0	15	------	15
Aug. 26 (Naval Observatory)	11	40	−80.0	25.3	+3.5	31	------	------
			+38.0	143.3	−3.0	9	------	40
Aug. 27 (Naval Observatory	11	9	−70.0	22.4	+3.0	46	------	------
			−42.0	50.4	+1.0	3	------	------
			+8.5	100.9	+4.0	15	------	------
			+32.5	124.9	−1.0	6	------	------
			+52.0	144.4	−3.5	3	------	73
Aug. 28 (Naval Observatory)	12	48	−55.0	23.3	+3.0	77	------	------
			−36.0	42.3	−8.0	31	------	------
			+8.0	86.3	+5.0	19	------	127
Aug. 29 (Naval Observatory)	11	26	−85.0	340.8	+4.5	15	------	------
			−42.0	23.8	+3.0	62	------	------
			−24.0	41.8	−9.0	------	19	------
			+21.5	87.3	+4.5	------	15	111
Aug. 30 (Naval Observatory)	10	46	−79.0	334.0	+5.5	9	------	------
			−69.0	344.0	+4.5	15	------	------
			−29.0	24.0	+3.0	62	------	------
			−10.5	42.5	−9.0	------	15	101
Aug. 31 (Naval Observatory)	10	46	−62.0	337.7	+6.0	6	------	------
			−55.0	344.7	+4.5	6	------	------
			−26.0	13.7	+11.0	------	93	------
			−17.0	22.7	+3.0	31	------	136
Mean daily area for August	----------		------	------	------	------	------	66

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, AUGUST, 1931

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen, Sternwarte, Zurich Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

August, 1931	Relative numbers	August, 1931	Relative numbers	August, 1931	Relative numbers
1	aa 23	11	8	21	10
2	Mccc 35	12	0	22	0
3	34	13	8	23	--------
4	28	14	0	24	0
5	28	15	0	25	0
6	19	16	0	26	Mc 8
7	8	17	Mc 11	27	Mcd 26
8	0	18	14	28	36
9	--------	19	14	29	25
10	0	20	10	30	24
				31	30

Mean, 29 days=13.8.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

LATE REPORTS

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JANUARY, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

January, 1931	Relative numbers	January, 1931	Relative numbers	January, 1931	Relative numbers
1	0	11	10	21	24
2	7	12	9	22	22
3	0	13	Mc 16	23	21
4	d --	14	41	24	--------
5	18	15	43	25	20
6	11	16	27	26	--------
7	11	17	Ec --	27	8
8	12	18	22	28	0
9	14	19	--------	29	7
10	a 11	20	a 25	30	0
				31	--------

Mean: 25 days=15.2.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR MAY, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

May, 1931	Relative numbers	May, 1931	Relative numbers	May, 1931	Relative numbers
1	17	11	33	21	Ec 30
2	8	12	26	22	26
3	7	13	a 32	23	35
4	8	14	17	24	32
5	8	15	Ec 36	25	31
6	17	16	37	26	Wc 35
7	d 17	17	29	27	35
8	26	18	--------	28	20
9	Mc 20	19	34	29	19
10	33	20	b --	30	d 20
				31	11?

Mean: 29 days=24.1.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JUNE, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

June, 1931	Relative numbers	June, 1931	Relative numbers	June, 1931	Relative numbers
1	13	11	20	21	0
2	Ec 28	12	14	22	7
3	34	13	0	23	0
4	36	14	Wc 10	24	0
5	a 30	15	0	25	0
6	36	16	0	26	0
7	32	17	0	27	Ec 8
8	Mc 44	18	7	28	10
9	35	19	0	29	d 25
10	47	20	0	30	23

Mean: 30 days=15.3.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. Gregg, in Charge]

By L. T. Samuels

In Table 1 are given the mean free-air temperatures and relative humidities for August for two kite stations, four Weather Bureau airplane stations, and four Navy airplane stations. Normal values are not available for all of these stations, but in most cases they have been determined for some near-by place. A comparison of these with the monthly means indicates small departures at the upper levels in most cases.

An interesting feature of Table 1 is the relatively low temperatures at the upper levels over Chicago as compared with those over Omaha. In this connection it is noted that the resultant free-air winds for the month contained an appreciably greater northerly component over Chicago than over Omaha. (See Table 2.)

At the 1,000-meter level the highest resultant winds occurred over southern Plains States, where they reached 9 meters per second with a strong southerly component. At 4,000 meters the resultant direction over this region was diametrically opposite with considerably lower velocities. Strong southerly components occurred at 6,000 meters over the extreme southern stations.

From Table 3 it will be seen that airplane observations were made on every scheduled day during the month, the maximum height being 7,242 meters, reached at Omaha on the 23d.

Table 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during August, 1931*

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (2 meters)	Omaha, Nebr.[1] (299 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)	Washington, D. C.[3] (2 meters)
TEMPERATURE (°C.)										
Surface	18.0	17.7	23.0	23.7	18.4	25.2	17.7	24.2	23.9	22.4
500	19.3	18.8	23.5	21.9	18.2	22.8	18.5	24.0	20.6	21.8
1,000	18.5	18.3	22.7	19.5	17.0	20.6	19.5	20.5	22.8	20.2
1,500	15.5	15.3	20.3	16.3	15.2	------	17.4	------	------	------
2,000	12.0	12.2	17.1	13.1	12.5	13.6	14.8	14.2	19.3	14.7
2,500	9.2	9.3	14.0	9.7	9.6	------	11.7	------	------	------
3,000	6.4	6.6	10.9	6.6	6.8	7.4	8.8	8.8	12.2	8.8
4,000	0.4	1.6	5.3	0.0	0.9	------	2.2	------	------	3.2
5,000	−5.7	−3.4	−1.3	------	------	------	−4.5	------	------	------
6,000	------	−8.4	−7.8	------	------	------	−11.8	------	------	------
7,000	------	------	------	------	------	------	−19.5	------	------	------
RELATIVE HUMIDITY (PER CENT)										
Surface	85	86	75	80	70	76	83	86	76	81
500	70	74	72	77	69	67	76	75	82	72
1,000	62	66	66	73	60	63	62	74	57	67
1,500	66	70	62	75	56	------	60	------	------	------
2,000	68	72	62	73	56	66	56	69	52	70
2,500	58	66	63	72	57	------	53	------	------	------
3,000	53	64	62	69	57	67	50	61	52	62
4,000	45	51	50	69	49	------	47	------	------	66
5,000	39	44	44	------	------	------	46	------	------	------
6,000	------	36	41	------	------	------	44	------	------	------
7,000	------	------	------	------	------	------	47	------	------	------

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

Table 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a. m. (E. S. T.) during August, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 47 E	0.6	S 37 E	0.6	S 6 E	1.7	N 70 W	2.8	S 89 W	0.8	S 6 W	1.2	S 36 E	1.7	N 61 W	0.2	N 68 W	1.3	S 72 W	0.7	S 55 W	0.6	S 78 E	2.3
500	------	---	S 13 E	7.1	S 48 W	1.8	------	---	N 79 W	2.2	S 77 W	2.2	S 6 W	7.1	N 64 W	2.2	N 84 W	1.0	------	---	S 71 W	2.6	S 72 E	5.6
1,000	------	---	S 12 E	7.5	N 67 W	3.1	------	---	N 63 W	2.8	N 75 W	3.2	S 32 W	7.3	N 80 W	3.0	S 65 W	3.3	S 87 W	1.9	S 80 W	2.4	S 69 E	5.3
1,500	------	---	S 16 E	6.0	N 58 W	4.3	------	---	N 67 W	3.7	N 80 W	3.6	S 35 W	4.8	S 88 W	3.7	S 87 W	4.1	N 88 W	3.2	S 79 W	2.2	S 75 E	3.8
2,000	S 17 E	1.3	S 26 E	5.4	N 57 W	5.2	N 81 W	3.8	N 73 W	4.1	N 74 W	4.5	S 53 W	2.9	S 76 W	4.6	N 80 W	5.3	N 84 W	5.4	S 82 W	2.0	S 80 E	2.8
2,500	S 25 W	1.4	S 30 E	4.5	N 66 W	6.0	S 76 W	3.4	N 48 W	3.5	N 65 W	4.9	N 40 W	2.5	S 81 W	5.4	N 70 W	7.6	N 88 W	6.5	S 66 W	2.8	S 74 E	2.8
3,000	S 61 W	1.4	S 41 E	2.4	N 63 W	7.3	S 86 W	3.4	N 34 W	3.9	N 73 W	5.3	N 10 W	3.5	S 87 W	5.0	N 75 W	8.2	S 88 W	6.7	S 75 W	3.4	S 79 E	3.0
4,000	N 31 W	0.5	S 22 E	0.8	N 73 W	6.1	N 70 W	4.2	N	5.2	N 37 W	3.0	N 13 E	5.0	N 84 W	6.2	N 66 W	7.9	N 88 W	8.8	S 67 W	3.7	S 50 E	3.3
5,000	N 16 E	1.9	------	---	------	---	N 54 W	3.8	------	---	N 4 E	4.9	------	---	S 77 W	6.0	N 38 W	7.3	N 89 W	10.8	S 13 W	2.6	S 60 E	2.6

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 75 E	0.1	S 34 W	0.4	S 18 W	1.4	N 62 E	0.4	N 75 W	0.9	S 5 E	2.1	S 22 E	1.4	S 73 E	2.5	S 37 E	3.1	N 87 E	0.5	S 32 E	0.8	N 2 E	0.7
500	S 78 E	1.0	S 84 W	0.8	S 57 W	4.4	S 9 E	0.4	S 60 W	2.0	S 7 W	4.9	S 4 W	3.5	S 67 E	3.1	------	---	S 50 E	1.7	N 25 E	1.0	N 12 W	3.3
1,000	N 64 E	0.6	N 66 W	1.2	S 75 W	4.7	S 22 W	1.0	N 83 W	2.9	S 31 W	9.2	S 34 W	5.2	S 57 E	1.6	------	---	S 79 W	1.8	N 13 E	2.6	N 32 W	2.8
1,500	S 24 W	0.6	N 87 E	0.6	S 88 W	4.4	S 20 W	1.8	S 78 W	3.0	S 53 W	5.5	S 72 W	4.2	S	0.7	S 30 E	4.8	N 82 W	3.1	N 6 W	2.6	N 48 W	4.6
2,000	S 18 E	1.7	S 26 E	0.8	N 59 W	2.3	S 39 W	1.4	S 48 W	3.8	S 76 W	2.5	N 85 W	3.9	S 51 E	0.2	S 1 W	4.3	N 71 W	4.4	N 35 W	1.4	N 60 W	5.3
2,500	S 27 E	3.5	S 31 W	3.2	N 43 W	2.8	S 53 W	1.8	S 37 W	5.2	N 41 W	2.7	N 62 W	4.3	S 25 E	0.9	S 33 W	2.5	N 54 W	4.7	N 59 W	1.6	N 67 W	5.2
3,000	S 30 E	5.4	S 32 W	5.4	N 36 W	2.6	S 70 W	2.2	S 44 W	7.0	N 14 W	2.6	N 33 W	3.8	S 49 E	3.5	S 64 W	3.1	N 35 W	5.3	N 55 W	4.2	N 70 W	6.7
4,000	S 45 E	3.3	S 44 W	8.1	------	---	N 89 W	2.8	------	---	N 18 W	2.3	N 35 W	4.8	------	---	S 78 W	5.1	N 19 E	4.8	------	---	N 60 W	5.1
5,000	------	---	------	---	------	---	N 79 W	2.4	------	---	------	---	N 10 E	5.5	------	---	N 66 W	8.3	N 11 E	4.8	------	---	------	---

Table 3.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during August, 1931*

	Dallas, Tex.[1]	Due West, S. C.	Ellendale, N. Dak.	Chicago, Ill.[1]	Cleveland, Ohio[1]	Omaha, Nebr.[1,2]
Mean altitudes (meters), m. s. l., reached during month	5,898	2,590	3,337	5,101	5,785	6,248
Maximum altitude (meters), m. s. l., reached	6,304	4,450	[3] 4,712	5,692	6,283	7,242
Number of flights made	31	26	32	31	31	24
Number of days on which flights were made	31	25	31	31	31	24

[1] Airplanes.
[2] Observations began Aug. 8.
[3] Limited-height sounding-balloon observation.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

[Climatological Division, Oliver L. Fassig, in Charge]

By M. C. Bennett

GENERAL SUMMARY

August, considering both temperature and precipitation for the whole country, was nearer a normal month than has been experienced for a long time. East of the Rocky Mountains the mean monthly temperature ranged generally but a degree or two above or below the normal, the Southern States being slightly below and the North slightly above the seasonal average. However, west of the Rocky Mountains the weather was generally warmer than the normal, while in the central portions of California the month was the hottest August of record.

Precipitation was above normal in the Atlantic States and considerable portions of the central Mississippi Valley and the far Southwest, while in the Great Plains area from western Kansas northward the precipitation was markedly deficient in some sections; large parts of South Dakota and Montana received less than one-fourth the normal, while much of the Pacific Northwest had practically a rainless month.

TEMPERATURE

The first decade was considerably hotter than normal from the middle Plains and the upper Mississippi Valley eastward to the middle Atlantic and New England coasts. Likewise the interior of the North Pacific States had some very hot days at this time, but most portions of Montana and North Dakota were cooler than normal. During the second decade and the first few days of the last decade most of the country from New Mexico and the middle Plains eastward was cooler than normal, the deficiency being quite marked in the lower Mississippi Valley; but during this period substantially all northern districts and practically all the country west of the Continental Divide were hotter than normal, the excess in Montana being about 8° per day.

The closing week of August brought a marked change in Minnesota, Wisconsin, and Michigan, where unseasonably cool weather prevailed. Most of the eastern half of the country likewise was cooler than normal, except the immediate Atlantic coast. The western half was hotter than normal, especially Nevada and central and southern California.

In every State August averaged within about 3° of normal, this being the first month since October, 1929, to be so close to normal throughout the Nation. Almost all northern and far western districts averaged warmer than normal, the excess being 2° to 3° or slightly more in a great part of the Lake region, and in most of Utah, Nevada, and eastern Oregon, and the northeastern, central, and southwestern portions of California. At several coast stations in California from San Francisco southward, also at Fresno, in the San Joaquin Valley, the month was the hottest August of record.

From New Mexico and western Kansas eastward to the south Atlantic coast the temperature averaged almost everywhere a little below normal, the greatest deficiency, about 3° a day, occurring in Arkansas and parts of the States adjoining.

The highest temperatures in the various States were 100° or more, save in New England, but were practically nowhere above 105° in the eastern half of the country. In the western half almost all States recorded 107° or higher, the very highest mark reported being 123° in southeastern California. In the eastern half the highest marks were noted during the first 10 days, but there was less uniformity in the West, though most of the Southwest noted the highest readings between the 18th and the 28th.

In a few Gulf and South Atlantic States which lack high mountains no reading lower than 50° was reported. In most States east of the Rocky Mountains the lowest marks were between 50° and freezing, but in Michigan, Wisconsin, and Minnesota several stations had temperatures considerably below freezing as the month ended, Wolverine, Mich., noting 24°. Temperatures about as low, or even lower, occurred at lofty stations in many far western States, the lowest of all being 17° in Colorado. The dates of lowest temperatures were largely within 10 days of the close of August, though in the central valleys and to southward and southeastward they were frequently noted about the 13th.

PRECIPITATION

The rainfall of August was fairly well distributed in point of time. From the middle and northern portions of the Rocky Mountain region eastward to the western part of the Lake region and the lower Ohio Valley there were widespread rains of importance during the first decade, and the portion of this area lying east of the Missouri River again had considerable rainfall during the final week. In the Atlantic and Gulf States the chief rains came between the 6th and the 24th. There was important rainfall in the far Southwest between the 3d and the 7th, then again during the very last days of the month.

The geographical distribution of the August rains was apparently better than usual in summer, though in many cases there were marked differences in amounts within short distances; yet, as far as reported, every station east of the Mississippi River and south of the Ohio and the southern limit of New York measured at least an inch during the month. The State average amounts were at least 2 inches everywhere east of the Rocky Mountain States, save in South Dakota and Michigan, where they were slightly less.

Within this area east of the Rocky Mountain States only the two States just named and Vermont failed to average 80 per cent of normal, and these three had about two-thirds of normal. No States here averaged more than 140 per cent of normal except a few in the upper Ohio Valley and the southern part of the middle Atlantic area. In general there was moderately more than normal in southern New England, North Carolina, Tennessee, and the central valleys. From western Kansas to northwestern and central Texas there was a moderate to considerable shortage.

In the far West conditions varied widely. The districts close to the Mexican border usually had much more rainfall than normal, and there was an excess in most of Nevada, northern Utah, southern Wyoming, and northeastern Colorado. A considerable deficiency was noted in Montana and northern Wyoming and everywhere to westward, practically no rain whatever falling in Oregon, western Idaho, or southeastern Washington.

The greatest monthly amount reported by a station in the United States proper was 15.73 inches, at Red

Springs, N. C. In the central part of the country Eureka Springs, Ark., led, with 14.67 inches, and in the far West, Helvetia, Ariz., with 11.27 inches.

SUNSHINE AND RELATIVE HUMIDITY

More than the average amount of sunshine was received in the central and northern plateau and Pacific coast regions, while much less than the normal amount for August was received in the central and southern portions of California, the southern plateau region, and in the far Southwest generally. Elsewhere sunshine was near the average, but slightly above in the Great Plains and slightly below in the East generally. The relative humidity was above the normal in the far Southwest, the north Pacific region, the central Mississippi and Ohio Valleys, and the Northern and Central Atlantic States. However, in all cases the averages were but slightly above the normal. Elsewhere the humidity was generally below the average, with minus departures rather pronounced in portions of the upper Mississippi and the Missouri Valleys and the northern Rocky Mountain region.

SEVERE LOCAL STORMS, AUGUST, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Woodburn, Iowa (northwest of).	1	3 p. m.	33		$500	Tornado	Corn and haystacks damaged; path 1 mile long.	Official, U. S. Weather Bureau.
Greenfield (near), Iowa	1	6 p. m.			5,250	do	Buildings and crops damaged	Do.
Mahaska County, Iowa	1				1,000	Wind squall	Trees uprooted; corn and fences leveled; telephone communication interrupted.	Do.
Johnstown, Pa.	2	5:15 – 7:20 p. m.			125,000	Hail and rain	3 small bridges washed away; many basements flooded; 4 persons injured.	Do.
Prairieton (near), Ind.	2					Wind and rain	Sheds, barns and crops damaged; many trees blown down.	Do.
Overbrook (near), Kans.	3	7:09 p. m.	30			Small tornado	Minor damage to a few buildings; corn injured; path 1.5 miles long.	Do.
Saratoga Springs, Glens Falls, and North Troy, N. Y.	3				200,000	Electrical and wind.	Hotel roof partially destroyed; damage to telephone, power lines and other property by falling trees.	Do.
Westport, Conn., and vicinity.	3			1	75,000	Electrical, wind, hail and rain.	Highways obstructed by fallen trees; wires blown down; windows and auto shields broken.	Hartford Times (Conn.).
Iuka, Kans., and vicinity	5	4:30 p. m.	880			Hail, rain and wind.	Injury chiefly to corn; power lines damaged; path 3 miles long.	Official, U. S. Weather Bureau.
Big Horn and Yellowstone Counties, Mont.	7				436,600	Hail	Much loss to buildings and crops; livestock killed.	Do.
Dallas County, Iowa	7	3 p. m.			1,700	Wind, squall	Telephone and trees damaged; plate glass broken.	Do.
San Elizario (near), Tex.	8	do	2,640			Hail	Crops almost total loss	Do.
Sturtevant, Wis.	8	5:15 p. m.			2,750	Wind, squall	Small farm buildings damaged corn lodged	Do.
Bucyrus (near), Ohio	8				1,000	Wind	Farm buildings and trees damaged; crops hurt.	Do.
Philadelphia, Pa., and vicinity north of.	10	5-8 p. m.			100,000	Rain and electrical.	Damage chiefly by flooding of basements and subway.	Do.
Reading, Pa.	10	P. m.			50,000	do	Mill partially destroyed; electric and telephone service crippled; crops leveled.	Do.
Between Woodfield and Etchison, Md.	10				5,000	Electrical	Large barn and contents destroyed	Do.
Sheffield Lake Village, Ohio.	11	10:30 p. m.	16–34		50,000	Probably tornado	Numerous cottages wrecked; overhead wires blown down; 10 persons injured.	Do.
Remsenburg, N. Y.	12	9 a. m.	10			Wind	Trees uprooted; several farm buildings damaged.	Do.
Salt Lake City, Utah, and vicinity.	13	P. m.			25,000	Heavy rain and wind.	Gravel pit equipment, railways, highways, residence and business properties damaged.	Do.
McClain and Garvin Counties, Okla.	16	4 p. m.	2 mi.		10,000	Hail	Damage confined to crops; path 8 miles long.	Do.
Denver, Fort Lupton, and Hudson, Colo.	16				151,500	do	Extensive damage to crops and other property.	Do.
Polk County, Iowa	18	3 p. m.			3,000	do	Farm property damaged	Do.
Concordia, Kans. (10 miles northeast).	18	5:30 p. m.	100		3,000	Small tornado	Damage chiefly to small farm buildings; path 1 mile long.	Do.
Due West, S. C.	18		7			do	Did not reach ground but crops directly under it were damaged.	Do.
Guthrie County, Iowa	19	4 p. m.	2 mi.			Wind and hail	Crops almost total loss in places; path 7 miles long.	Do.
Iowa County, Iowa	19				6,000	do	Buildings and crops damaged	Do.
Filmore County, Nebr.	20	3-4 p. m.	3 mi.		35,000	Hail and wind	Chief damage to crops; a few windmills and trees blown down; path 18 miles long.	Do.
New Braunfels (near), Tex.	20	8:25 p. m.			500	Tornado and hail.	Crops completely destroyed in small area; minor damage to buildings.	Do.
Richmond, Va.	20				20,000	Rain	Industrial plants flooded, walls, sidewalks, and pavements undermined; telephone service crippled.	Do.
Leesville (near), N. C.	21	3 p. m.			30,000	Wind and rain	Chief damage to crops	Do.
Olton (near), Tex.	21	5 p. m.	2 mi.			Hail	Severe injury to crops; some stock loss	Do.
Ione (near), N. Mex.	22	11 p. m.	2 mi.			do	Considerable damage, character not reported.	Do.
Chesapeake Bay and Eastern Shore, Md.	22–23					Wind and rain	Corn flattened; tomatoes damaged; fruit blown off; wires broken; boats driven ashore.	Do.
York and Seward Counties, Nebr.	25	3-4 p. m.	3 mi.		20,000	Hail and wind	Much crop damage; poultry killed; path 20 miles long.	Do.
Centrahoma to Atoka, Okla.	25	4:30 p. m.	880–3,520		14,000	Hail	Crops damaged; path 20 miles long	Do.
Jefferson County, Nebr.	25	4:30–5 p. m.			60,000	do	Considerable crop loss	Do.
Bryan County, Okla. (southwestern).	25	7 p. m.	1,760		26,000	do	Crops damaged; path 9 miles long	Do.
Frederick County, Md.	25					Hail and wind	Corn stripped; trees blown down	Do.
Lenoir City, Tenn.	26				10,000	Electrical	Residence destroyed	Do.
Cerro Gordo County, Iowa.	27	1-1:30 p. m.	25–34	1	160,000	Wind, hail, and tornado.	Pavilion, theater, numerous cottages and trees damaged or wrecked; crops injured; path 7 miles long; tornado near Clear Lake; 21 persons injured.	Do.
Fayette County, Iowa	27	3:30 p. m.				Wind, hail, and electrical.	Heavy crop loss; telephone service disrupted; 40 cows killed.	Do.
Buchanan County, Iowa	27	4 p. m.			10,000	Hail	Windows, roofs, and auto tops pierced; crops hurt; poultry killed.	Do.
Muscatine County, Iowa	27	5 p. m.	70		12,000	Wind and tornado.	Tornado near Muscatine; damage on 3 farms; path 6 miles long.	Do.

[1] "Mi." signifies miles instead of yards.

SEVERE LOCAL STORMS, AUGUST, 1931—Continued

Place	Date	Time	Width of path yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Bushton (near), Ill	27	5 p. m.	2,640		13,000	Hail	Crops and roofs damaged; glass broken; path 3 miles long.	Official, U. S. Weather Bureau.
Charleston, S. C. (north of)	27	6 p. m.			1,500	Thunderstorm and wind.	Damage to crops and outhouses	Do.
Rock County northeastward to Lake Michigan, Wis.	27	7 p. m.				Thunderstorm and wind squalls.	Trees uprooted; poles and overhead wires blown down; corn lodged.	Do.
Chickasaw, Floyd, Scott, Wright, and Delaware Counties, Iowa.	27	P. m.				Wind and hail	Crops, roofs, farm buildings and equipment, and trees damaged.	Do.
Delphi, Ind. (3 miles west)	27	do			5,000	Small tornado	Barn and several small buildings wrecked; trees blown down.	Do.
Linn and Jackson Counties, Iowa.	27	do				Wind, rain and flood.	Sewers and cellars flooded; wires damaged; railway track and 8 bridges washed out.	Do.
Jo Daviess, Carroll, Lake, and Whiteside Counties, Ill.	27					Wind and electrical.	Number of buildings struck; barns burned; stock killed; wire services crippled; orchards hurt.	Do.
Norwich, Oneonta, and Goshen, N. Y.	27					Heavy rain	Basements and low lands flooded.	Do.
Providence, R. I., and vicinity.	27–28					Thunderstorm	12 houses struck by lightning; many telephones out of order.	Do.
Sparta, Ill., and vicinity	28	2 a. m.	20–30		50,000	Probably tornado	Roofs torn off; two-story brick building practically demolished; windows and walls pushed out.	Do.
Carlsbad (near), N. Mex.	28	4 p. m.	1,760		32,000	Hail	Much cotton destroyed or damaged	Do.
Emmitsburg, (near), Md.	28	P. m.			10,000	Thunderstorm and wind.	Garage and small buildings burned or wrecked; trees uprooted.	Do.
Yuma, Ariz	29					Hail, wind, and rain.	Skylights, windows, and trees broken; small farm buildings demolished; cotton hurt.	Do.
Benton, Black Hawk, Carroll, Marshall, Story, and Monroe Counties, Iowa.	31	6:10 p. m.			44,000	Wind	Buildings, crops, trees, and overhead wires damaged.	Do.
Riley County, Kans	31	6:30 p. m.	6 mi.		50,000	Wind and hail	Barn and pavilion wrecked; crops damaged; windows and light globes broken; roofs pierced; 1 person injured; path 7 miles long.	Do.
Volland to Maple Hill and Eskridge, Kans.	31	9:45 p. m.	2–10 mi.		25,000	do	Windows broken; roofs and crops damaged; path 25 miles long.	Do.
Southeastern counties, Wis.	31	P. m.			12,000	Wind, squalls, thunderstorm, and hail.	Considerable damage to farm properties; tobacco injured.	Do.

[1] "Mi." signifies miles instead of yards.

RIVERS AND FLOODS

(River and Flood Division, Montrose W. Hayes in Charge)

By RICHMOND T. ZOCH

Important overflows occurred in the southeastern part of the country and in the Colorado River basin. The accompanying table of floods shows the crests reached.

Damage was reported as follows: In the Roanoke River system, $7,000; in the Neuse River system, $8,000; in the Cape Fear River system, $5,000; in the Peedee River system, $3,000; and in the Colorado River system, $3,000. The damage caused by high water in the Pearl River system was given in the July issue of the MONTHLY WEATHER REVIEW. There were no reports of losses received from the Tar or Santee River systems.

The value of property saved by warnings was, along the Roanoke River, $16,000; the Tar River, $1,000; the Neuse River, $6,000; the Cape Fear River, $8,000; and the Peedee River, $25,000.

Heavy local rains resulting in overflows in small streams, where it is impracticable to maintain a warning service, caused damage as follows: On August 1, $100,000 around Helena, Mont., and $50,000 around Sioux City, Iowa; and on August 13, $25,000 around Salt Lake City, Utah. Other overflows in small streams were reported, but the extent or amount of damage was not given.

Most of the rivers of the Mississippi system, except those in the Ohio basin, were at the lowest stages ever recorded in a summer month. Most of the rivers in California were also extremely low.

Table of flood stages in August, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	Feet			Feet	
Roanoke:					
Randolph, Va	21	23	24	21.4	24
Weldon, N. C	30	24	25	34.1	25
Scotland Neck, N. C	23	13	13	23.0	13
		24	26	25.2	26
Williamston, N. C	9	13	19	9.8	18
		26	31	9.9	30
Fishing Creek: Enfield, N. C	15	13	15	15.4	14
Tar: Rocky Mount, N. C	9	13	13	9.2	13
Neuse:					
Neuse, N. C	15	5	6	17.0	5
Smithfield, N. C	14	1	2	14.5	2
		5	8	19.0	7
		12	17	16.8	13
		23	23	14.0	23
Cape Fear:					
Fayetteville, N. C	35	23	24	36.2	23
Elizabethtown, N. C	22	14	16	22.7	16
		22	26	29.0	24
Peedee:					
Cheraw, S. C	27	22	23	30.0	23
Mars Bluff Bridge, S. C	17	24	30	19.5	27
Poston, S. C	18	29	31	18.9	30, 31
Santee: Rimini, S. C	12	12	18	13.0	14, 15
		30	30	12.0	30
EAST GULF OF MEXICO DRAINAGE					
Pearl: Jackson, Miss	20	[1] 29	10	26.4	5
GULF OF CALIFORNIA DRAINAGE					
Gila: Gila Bend, Ariz	5	10	11	7.5	11
Colorado: Parker, Ariz	7	6	6	9.5	6

[1] In July.

All dates are in August, unless otherwise indicated.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By the Marine Division, W. F. McDonald, in charge]

NORTH ATLANTIC OCEAN

By W. F. McDonald

The normal pressure distribution over the Atlantic was considerably disturbed during August, 1931, especially in the latter half of the month. Extensive development of the usual Atlantic HIGH prevailed only during rather brief periods, comprising a few days at the beginning and end of the month and the interval between the 10th and 15th.

Even in this period, however, while high pressure conditions were dominant over most of the Atlantic, there was a storm development near the American coast, and the American steamship *Onondaga* encountered a gale of force 10, approaching New York from the southward on August 11. This disturbance did not show further development or progress, however, but diminished and disappeared within the next two days; but simultaneously with its disappearance there was development of a vigorous depression southeast of lower Greenland, which moved slowly southeastward deepening as it progressed. On the 13th the American steamship *Seattle Spirit*, bound from Bremen to Boston, ran into winds of gale force that culminated on the 14th in the strongest winds reported from any part of the Atlantic during the month (force 11), and this same disturbance moved over the British Isles with diminished intensity on the 17th, causing some damage by high winds and heavy rains.

A succession of slow-moving disturbances then began to cross the Atlantic, and it was not until the month was well along that the HIGH reestablished itself over the western part of the ocean, while there remained several sharp disturbances over the eastern portion of the main steamer routes. Considering the season, an unusual number of gales was reported between the 15th and 27th, with several ships encountering winds of force 10 in the eastern Atlantic. Press reports indicated that several passenger liners were diverted or slightly delayed in making their schedules.

The average pressure situation for the month as a whole (see Table 1) reflected this concentration of LOW movements across mid-ocean on paths more southerly than usual, in that averages were below normal over most of the area between 30° and 50° N. latitude, and above normal in surrounding areas, with the greatest excess lying to eastward of Greenland.

August was free from serious West Indian disturbances, although two very mild depressions were noted in the Caribbean Sea in the period from the 11th to the 17th. The first of these crossed the full length of the Caribbean from east to west, moved into Yucatan on the 16th, and passed near Frontera, Mexico, on the next day when the Honduran steamship *Morazan*, lying in port at Frontera, experienced a gale of force 9, together with a wind change characteristic of the central area of a tropical disturbance.

Fogs on the north Atlantic during August were confined, so far as our reports indicate, to areas north of latitude 40. They decreased greatly as compared with the previous month, being most extensive between the Grand Banks and the vicinity of Nantucket from the 7th to the 16th, with rather extensive fogginess still earlier in the month between the Grand Banks and the British Isles.

The reports indicate a great decrease in fogginess after the 17th with occurrence mainly in scattered banks and patches rather than in widespread blanketing of the steamer routes. It is worthy of note that the great reduction in fog appears to have been about coincident with the appearance of the series of disturbances noted above, which marked the disruption of the normal pressure distribution over the Atlantic.

Table 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, August, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Julianehaab, Greenland [1]	29.98		30.32	20th	29.65	2d.
Reykjavik, Iceland [1]	29.94	0.13	30.32	29th	29.36	26th.
Lerwick, Shetland Isles [1]	29.95	0.15	30.36	29th	29.46	16th.
Valencia, Ireland [1]	29.90	−0.02	30.42	11th	28.95	16th.
Lisbon, Portugal [1]	30.06	0.04	30.30	22d	29.83	24th.
Madeira [1]	30.09	0.07	30.28	30th	29.96	4th.
Horta, Azores [1]	30.11	−0.09	30.31	1st	29.74	25th.
Belle Isle, Newfoundland [1]	29.94	0.05	30.30	13th	29.22	1st.
Halifax, Nova Scotia [1]	30.00	−0.01	30.36	14th	29.70	10th.
Nantucket [2]	30.01	0.02	30.40	14th	29.64	10th.
Hatteras [2]	30.04	0.04	30.32	15th	29.74	10th.
Bermuda [1]	30.13	−0.01	30.36	13th	30.00	6th.
Turks Island [1]	30.10	0.06	30.14	2d	30.02	7th.
Key West [2]	30.03	0.05	30.12	24th	29.92	14th.
New Orleans [2]	30.06	0.08	30.25	24th	29.89	10th.

[1] All data based on a. m. observations only, with departure computed from best available normals related to time of observation.
[2] Corrected 24-hour means, based on more than one observation daily.

OCEAN GALES AND STORMS, AUGUST, 1931

Vessel	Voyage, From—	Voyage, To—	Position at time of lowest barometer, Latitude	Position at time of lowest barometer, Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
General Greene, Am. S. S.	St. Johns	Labrador	59 28 N	44 28 W	Aug. 1	11 p., 2	Aug. 2	29.00	NE	NE	N	ENE, 9	NE-N.
West Harcuvar, Am. S. S.	Bremen	Boston	53 30 N	39 52 W	Aug. 2	1 a., 2	do	29.46	SSW	SW, 7	SW	SW, 8	
Baron Kelvin, Br. S. S	Cape Town	Calais	47 25 N	5 40 W	Aug. 8	8 a., 8	Aug. 9	29.47	NW	WNW, 8	WSW	NNW, 8	NW-W-NNW.
Onondaga, Am. S. S	Canal Zone	New York	39 37 N	73 50 W	Aug. 11	6 p., 11	Aug. 12	29.69	NNE	NNE	N	NNE, 10	
Lustrous, Br. S. S	Houston	Hamburg	47 22 N	33 00 W	Aug. 12	10 a., 12	do		SW	SW, 7	N	SW, 8	SW-N.
Seattle Spirit, Am. S. S	Bremen	Boston	50 20 N	20 00 W	Aug. 13	8 a., 14	Aug. 15	29.03	NW	NW, 11	NNW	NW, 11	
Ohioan, Am. S. S	New York	Los Angeles	15 15 N	76 10 W	do	4 a., 14	Aug. 14	29.86	E	E, 9	E	E, 9	
Lustrous, Br. S. S	Houston	Hamburg	49 17 N	15 50 W	do	Noon, 15	Aug. 17		NW	WNW, 8	SW	WSW, 9	NW-W.
Boston City, Br. S. S	Bristol	Wilmington	51 20 N	7 26 W	Aug. 15	8 a., 16	do	28.96	S	SSW, 8	WSW	SSW, 8	SSW-WSW.
New York, Gr. S. S	Cherbourg	New York	49 45 N	12 00 W	do	4 p., 15	Aug. 15	28.85	SW	SW, 9	WNW	SW, 9	SSW-WSW.
Jason, Du. S. S	Amsterdam	Canal Zone	47 01 N	9 19 W	do	do	Aug. 16	29.25	SW	WSW, 8		WSW, 8	WSW-WNW.
Berlin, Gr. S. S	Bremerhaven	New York	49 53 N	10 54 W	do	12 mid., 15	do	29.16	SW	SW, 8	W	—, 9	S-W.
Morazan, Hon. S. S	New Orleans	Mexico	18 38 N	92 44 W	Aug. 17	Mid., 17	Aug. 17	29.74	NW	NW, 8	S	NW, 9	NW-S.
Statendam, Du. S. S	New York	Rotterdam	42 16 N	49 50 W	do	2 p., 18	Aug. 18	29.52	NNW	ESE, 5	S	ENE, 8	NE-E.

OCEAN GALES AND STORMS, AUGUST, 1931—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN—Continued			° ′	° ′				Inches					
Independence Hall, Am. S. S.	Bordeaux	New York	47 00 N	8 48 W	Aug. 19	8 a., 19	Aug. 20	29.52	W	WSW, —	WNW	WNW, 9	WSW-WNW.
De Grasse, Fr. S. S	Plymouth	do	44 24 N	46 15 W	do	6 p., 19	do	29.78	SW	WSW, 6	WNW	WNW, 8	WSW-WNW.
Jean Jadot, Bel. S. S	New York	Antwerp	44 23 N	43 35 W	do	4 p., 20	Aug. 21	29.67	WNW	W, 9	N	NNW, 9	W-NNW.
Brave Coeur, Am. S. S	New Orleans	London	38 12 N	69 24 W	Aug. 22		Aug. 25	29.91	NE	NE, 7	SSW	E, 8	NE-SE-SSW.
Selma City, Am. S. S	Canal Zone	Portsmouth	38 01 N	72 18 W	do	2 p., 22	Aug. 23	29.90	NE	NE, 8	NE	NE, 8	ENE-NE.
Binnendijk, Du. S. S	Port Said	Boston	41 29 N	28 38 W	Aug. 24	6 a., 25	Aug. 25	29.41	S	S, 8	NW	N, 9	SSE-S-N.
Cerinthus, Br. S. S	France	Port Arthur	40 36 N	27 32 W	do	9 a., 25	Aug. 26	29.40	SSE	SSW, 6	NNW	NNW, 8	SSW-NNW.
Middleham Castle, Br. S. S.	Antwerp	Corpus Christi.	49 30 N	4 45 W	do	10 p., 24	Aug. 25	29.25	SE	NE, 8	NNE	E, 9	SE-NNE.
Asia, Dan. T. S	do	Cristobal	49 30 N	5 50 W	do	—, 24	do	29.20	E	ENE, 10	NE	ENE, 10	ESE-ENE.
Do	do	do	47 05 N	21 45 W	Aug. 25	—, 25	Aug. 27	29.12	SE	SE, 5	N	N, 10	S-SE-NW.
West Harshaw, Am. S. S.	London	New Orleans	42 55 N	22 45 W	do	Noon, 25	do	29.54	S	SSW, 9	WNW	SSW, 9	S-SW.
Barbadian, Br. S. S	Liverpool	Bermuda	44 10 N	22 42 W	do	8 p., 25	do	29.00	SE	S, 7	N	W, 10	S-W.
Hybert, Am. S S	Bremen	Tampa	44 45 N	22 35 W	do	10 a, 26	do	29.04	SSE	SSW, 9	NW	SSW, 9	SSE-SW-NW.
Middleham Castle, Br. S. S.	Antwerp	Corpus Christi.	42 30 N	17 15 W	Aug. 26	4 p., 27	Aug. 28	29.71	SE	SW, 7	WNW	W, 8	SE-WNW.
Baron Kelvin, Br. S. S	Swansea	Providence	50 20 N	26 52 W	do	Noon, 26	Aug. 27	29.79	E	NE, —	NNW	NE, 9	
France, Fr. S. S	New York	Le Havre	49 10 N	22 19 W	do	6 a., 26	do	29.55	NNE	ENE, 7	E	ENE, 9	
NORTH PACIFIC OCEAN													
Liberator, Am. S. S	Honolulu	Shanghai	30 14 N	129 25 E	Aug. 17	Noon, 17	Aug. 18	29.30	SE	SE, —	S	SE, 9	SE-S.
Tamaha, Br. S. S	Shanghai	San Pedro	31 45 N	123 50 E	Aug. 24	4 p., 25	Aug. 27	29.30	NE	ESE, —	SW	S, 10	E-ESE.
San Diego Maru, Jap. M. S.	Yokohama	Los Angeles	43 14 N	173 40 W	Aug. 27	8 p., 27	Aug. 28	[1] 29.18	S	S, 8	WSW	SSW, 8	S-SW.
Atago Maru, Jap. M. S	do	San Francisco	47 35 N	176 00 W	Aug. 29	2 p., 30	Aug. 31	28.91	SSE	SW; 8	W	SW, 9	
Brunswick, Pan. M. S	Sydney, N. S. W	Los Angeles	18 33 N	143 22 W	Aug. 30	11 p., 30	do	[2] 28.82	NE	N, 11	SE	N, 11	N-NW-W.
SOUTH PACIFIC OCEAN													
Laurel, Swed. M. S	San Pedro	Port Lyttelton.	36 50 S	177 10 W	Aug. 1	8 p., 1	Aug. 2	[1] 29.46	WNW	W, 10	WSW	W, 10	Steady.
Golden Eagle, Am. S. S	Los Angeles	Melbourne	21 14 S	179 38 W	Aug. 4	11 p., 4	Aug. 6	29.76	SE	SE, 8	SE	SE, 9	
Do	do	do	36 46 S	152 51 E	Aug. 13	9 p., 13	Aug. 14	29.88	N	NNW, 7	NW	NNW, 8	NNW-NW.
INDIAN OCEAN													
Fairfield City, Am. S. S.	Manila	Aden	11 55 N	52 45 E	Aug. 6	4 p., 10	Aug. 10	29.56	SW	WSW, 8	SW	SW, 10	

[1] Barometer uncorrected. [2] Barometer reading approximate.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—The north Pacific anticyclone was the controlling factor of the weather during the greater part of August, 1931, over most of the eastern half of the ocean. In the Aleutian and lower Alaskan region pressure for the most part continued little affected by cyclonic influences until after the 20th. About the 22d a tendency toward lower pressures was observed in northern waters, and on the last three days of the month a deep cyclone developed, the minimum barometer reading at Dutch Harbor being 28.82 inches, on the 30th. The average pressure at this station, however, as elsewhere among the northern islands and along the American coast, was above normal for August. At Midway Island the average for the month was below normal, and thence westward to the Asiatic coast pressure generally was comparatively low, owing to the prevalence of numerous cyclonic disturbances in the Far East.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, August, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1] [2]	29.99	+0.10	30.44	24th	29.70	13th.
Dutch Harbor [1]	29.97	+0.11	30.44	9th	28.82	30th.
St. Paul [1] [3]	29.93	+0.15	30.28	8th	29.02	30th.
Kodiak [1] [3]	29.92	+0.06	30.22	8th [4]	29.08	31st.
Midway Island [1]	29.99	−0.09	30.08	10th [4]	29.90	20th.[4]
Honolulu [5]	30.01	0.00	30.07	23d	29.90	16th.
Juneau [5]	30.05	+0.03	30.23	5th	29.66	31st.
Tatoosh Island [5] [6]	30.10	+0.10	30.27	26th	29.86	9th.
San Francisco [5] [6]	29.95	+0.03	30.12	14th	29.77	2d.
San Diego [5] [6]	29.92	+0.03	30.04	31st	29.77	2d.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] For 30 days.
[4] And on other date or dates.
[5] A. m. and p. m. observations.
[6] Corrected to 24-hour mean.

Cyclones and gales.—The weather along the upper steamship routes during August may be described as having the inconvenience of low visibility and much fog, though few of

the dangers of high winds and accompanying rough seas. Indeed, it was not until the last decade of the month, or between the 22d and 30th, as gathered from numerous reports that winds of gale velocity actually occurred in the northern trans-Pacific latitudes. These included two days with gales of moderate force, a day with a fresh gale, and a fourth day with a wind of force 9, all occurring within the region 42° to 48° N., 175° E. to 170° W. This was during the period of revival of the Aleutian low.

Tropical storm activity was of marked importance in the weather of Asiatic waters for the first time since the beginning of the year. A full report on the several typhoons that occurred there, prepared by the Rev. Miguel Selga, S. J., of the Philippine Weather Bureau, appears elsewhere in this issue of the Review, and the storms therefore need no further description. It may be added however, that the typhoon which entered the China coast on the 9th and 10th and continued far inland, was probably mainly responsible for the heavy rains which caused the serious flood conditions in the Yangtse River near Hankow. Conditions attending the later typhoons of the 17th to 18th and the 24th to 26th served to aggravate the flood situation and increase the sufferings of the many thousands of homeless and hungry Chinese.

An intense cyclone was experienced on the 30th and 31st in the southeastern Pacific by the Panaman motor ship *Brunswick*, Capt. P. A. Yorgensen, observer A. Graüningsater, Sydney to Los Angeles. Said the observer:

The storm started August 30 with increasing NE. wind. At noon 30th in 18° 00′ N., 143° 52′ W., barometer 29.63 (approximate), wind NE., 8. During day gradually increasing wind and sea. At 10.11 p. m., in 18° 33′ N., 143° 22′ W., barometer dropped rapidly to 28.94 (approx.) and was ranging between 28.94 and 28.82 for about 15 minutes, while wind shifted N.-NW.; later rising barometer with wind shifting to W., SW., and S., and finally settling down on SE., where it blew out during next 24 hours. The maximum wind was from N., force 11. Temperature over 80°. Weather hazy with rain.

This is the fifth tropical cyclone known to form thus near and to the eastward of the Hawaiian Islands in the last 22 years.

While no cyclones occurred this August off the west coast of Mexico, a moderate northwest gale was experienced on the 15th in the Gulf of Tehuantepec during the existence of a depression in the Gulf of Honduras, and a local gale occurred on the morning of the 19th during a flurry at the mouth of the Gulf of California. During a 3-hour electrical storm on the 11th in 8° 55′ N., 85° 07′ W., the American steamship *K. R. Kingsbury* was reported "struck by lightning six or seven times."

Winds at Honolulu.—The prevailing wind direction at Honolulu was east, with northeast as next in frequency. The maximum velocity was 24 miles from the northeast on the 6th.

Fog.—Along the northern routes fog was slightly less frequent as a whole than in July, but was still a factor of great importance, since it occurred on 20 to 50 per cent of the days over much of the ocean between about 42° and 52° N., to the westward of about 150° W. The region of maximum occurrence here was south of the central and western Aleutians. Off the American coast between central California and the mouth of the Columbia River there was more fog than in the previous month, with a maximum of approximately 15 days on which it was observed to the northward of Eureka. South of San Francisco fog decreased sharply in occurence to the central coast of Lower California, where reports of it ceased.

TYPHOONS OF AUGUST, 1931

By Rev. Miguel Selga, S. J.

[Weather Bureau, Manila, P. I.]

The first seven months of the year 1931 were unusually free from typhoons in the Philippines. The typhoon season having been delayed, there was in many regions a general complaint of lack of rain, which threatened to affect adversely the crop of rice. By the end of July the typhoon season had set in and the rains that in Manila had been 73 per cent below normal up to the end of July were 150 per cent above normal by the end of August.

The Pratas typhoon—July 29 to August 2, 1931.—The first certain indications of this typhoon are found in our weather maps of July 29, when the barometers began to fall gradually in the Philippines. The isobars of the 2 p. m., weather map of July 29 and the wind directions, which were northeast in northeastern Luzon, northwest in southern Luzon and Samar, westerly in southern Leyte, southern Samar and Surigao, south by west in Palau, and southeast in Yap, pointed to a center of a disturbance that was tentatively located within a hundred miles of 15° N. and 127° E.

On the afternoon of July 29 all ships were warned by radio, and Provinces of the islands were notified by telegraph that there was a depression over the Pacific three or four hundred miles east of Luzon. The barometric gradient at 6 a. m. on July 30 indicated that the center of the typhoon was to the east of Baler Bay. A convergence of cirrus toward the east-southeast observed at Basco at 6 a. m. is worth recording here. The usual drift of air at cirrus level in our latitudes is from the east and seems to act, as component force from the east, on the cirri radiated out from a typhoon center and at a considerable distance from the vortex. From an analysis of 37 former observations of cirrus directions in the front quadrants of typhoons, Mr. Leo G. Welch, S. J., of Manila Observatory, has found that in 19 cases the cirri were diverging exactly radially from the center, and in 15 cases the directions were less than 45° off from radial divergence, and that the lack of radial divergence could in every case be explained by a component force from the east. Three cases for unknown reasons are in apparent contradiction to the rule. Undoubtedly the convergence observed at Basco was due to the typhoon and could be taken as a fair precursory sign. All along the eastern coast of Luzon, as well as in Basco, the pressure had fallen 2 mm. from 6 a. m. of the 29th to 6 a. m. of the 30th. The center was plotted out to be near 16° 30′ N., 126° 10′ E., moving northwest by north. It continued in this direction until 2 p. m., when it was located at approximately 18° 50′ N., 125° E. Here it changed its course to west-northwest, due to a high pressure center over Japan which was increasing and causing the barometers to rise even in Oshima and Shanghai. Advancing in its westerly motion, the typhoon was at 6 p. m. in the center of the Balintang Channel, between Aparri and Basco.

A cablegram was dispatched to Hong Kong at 9 p. m. on July 30 to warn the colony of the sudden and dangerous turn of the typhoon. Maintaining its west-northwesterly course, the center of the typhoon passed over the Pratas shoal at 8:30 p. m., July 31, when the barometer of Pratas Observatory registered the minimum of 740.9 mm. The wind that at 5 p. m. was blowing from the north with force 7–8 dropped to a dead calm at 7:30 p. m. and remained absolutely still for two hours until 9:30 p. m.,

when it sprang from the south-southwest with force 8. In the three and a half hours immediately preceding the minimum, the barometer dropped 4.85 mm., but it gained 7.10 mm. in the two and a half hours following the barometric minimum.

Very early in the morning on August 1 precautions were taken in Hong Kong to minimize the effects of the typhoon that was threatening to strike the colony about noon. Ships sought safety in Typhoon Bay. The wind increased in force at 8 a. m. and from noon to 4 p. m. it was blowing a gale, while the typhoon was making its way to the continent between Hong Kong and Macao. The easterly gale of the afternoon blowing straight against the harbor of Hong Kong dashed the waves against the sea wall, sending volumes of spray into the air. The eastern end of Queen's Pier was badly damaged, big blocks of granite and concrete being flung into the harbor and on to the Praya. Due to the timely warnings issued by the Hong Kong Observatory, the colony escaped the blow fairly lightly. Typhoon signal No. 10 was hoisted in Hong Kong for the first time after the adoption of the new system of typhoon signals recommended by the Conference of Directors of Far Eastern Weather Services in 1930.

The Japanese steamer *Ryusei Maru* was reported in distress, having run into the center of the typhoon, 50 miles east-southeast of Hong Kong. The *President Jefferson* rode out the storm safely in Typhoon Bay, Hong Kong. Its wind veered from northeast, force 7, at 11 a. m. to southeast, force 4, at 7 p. m. Its lowest barometric reading was 743.4 mm. at noon; its strongest winds were from the east-northeast, force 11–12, at 1 p. m. Inland the typhoon weakened and seems to have filled up on August 2.

This typhoon increased in force of wind and depth of barometer from the Philippines to Hong Kong. It caused a very modest amount of rainfall, but no severe squalls, in the Philippines.

The Waishing-Kwongsang typhoon.—August 6–12, 1931.—From August 2 to 6 the weather of northern Luzon remained unsettled, with low barometer, light winds, and constant indications of shallow depressions. Our afternoon weather map of August 7 showed a typhoon at a considerable distance northeast of Aparri. It remained almost stationary or curved slowly until the afternoon of August 8, when it started off toward the north. On the afternoon of August 9, it appeared almost southeast of Ishigakijima. Pushed backward by the high pressure over Japan, the typhoon changed its course and headed off toward the northwest, passing very close to the northeast of Ishigakijima. The pressure at this station at 11 a. m. on August 9 had fallen to 739.5 mm., with north-northwest winds of force 6. Retaining its northwesterly direction, the typhoon passed 50 or 60 miles to the north of Keelung, Formosa, crossed the northern entrance of the Formosa Channel, raising mountainous seas and causing terrific winds, and entered the continent between Foochow and Wenchow in the morning of August 10. With a constantly increasing and gradual inclination to the west, the typhoon moved toward the interior of China for over 600 miles and seems to have filled up on August 12 in the Province of Kweichow.

Many ships were seriously affected by the strong winds and seas caused by this typhoon, especially along the China coast.

The *Susana II* rode out the storm in the harbor of Keelung while coaling. Her barometer dropped to 740.2 mm. on August 10 at 1 a. m., with winds from the west, force 5.

While the typhoon was crossing the northern entrance of the Formosa Channel the 5,000-ton steamer *Benarty* of the Ben Line was lashed by hurricane winds and pounded by mountainous seas for eight hours north of Swatow. "It was the worst experience of my life," said the master of the ship in reporting the terrific gale, with squalls often exceeding 100 miles an hour. The chief engineer was washed overboard by a huge wave; a lifeboat, being hurled over the side, was smashed to pieces by the power of the seas.

The 1,865-ton steamer *Waishing* of the Indo-China S. N. Co., bound from Hong Kong to Shanghai, encountered tremendous seas on August 10 after passing Foochow and, finding herself unable to battle against the elements, took refuge in Nam Kwan Bay, but, overtaken by the typhoon, the ship was driven ashore by the violence of the seas, was badly holed, and left in a precarious condition on the rocks. It is stated that the *Waishing* had hardly struck the rocks when pirates swarmed about, making off with everything they could lay their hands on. To prevent further pillage, and while waiting for the arrival of rescue ships in answer to the S O S calls, a perimeter camp had to be formed ashore, gathering the survivors on top of a small hillock and mounting guard with one revolver that had been salvaged from the wreck. One of the ships to answer the S O S call was the *Kwongsang*, of the same Indo-China S. N. Co., bound from Shanghai to Hong Kong. She seems to have been off Fu Island, just 30 miles of the Nam Kwan Bay, headed to the assistance of the *Waishing*, when she foundered after a furious battle against the typhoon. The *Kwongsang* carried 6 European officers and a crew of 56 Chinese. Bodies of many victims washed ashore, and stories of local fishermen of Fu Yan and Funingfu all point to the probability that no passenger escaped the disaster of *Kwongsang*.

Our own steamship *President Jefferson*, with many and prominent passengers on board, passed very close to the center of this typhoon on August 10 between Foochow and Wenchow and experienced winds of force 8 to 10 for over six hours.

The China Sea typhoon, August 7–20, 1931.—From August 7 to 12 a low-pressure area prevailed over the China Sea from northern Annam to Luzon. On the morning of August 13 it was evident that a well-defined center had developed in the trough of the low pressure, which had deepened considerably on the 12th. It had moved to the north of Macclesfield Bank by Friday afternoon and developed into a typhoon very early in the morning of August 15, moving north. The U. S. S. *Simpson*, laboring under heavy seas 60 miles west by south of Koshun, reported east-southeast winds of force 8 at 6 a. m. on August 15. The typhoon inclined to east-northeast, passed south and east of Pratas in the afternoon of August 15, and recurved to northwest at night approaching Bias Bay. The lowest barometric reading at Pratas was 739.80 mm. at 3 p. m. with winds from north-northeast and force 3, three hours previously the barometer read 742.09 mm., with east-northeast winds of force 6, while at 6 p. m. the wind had backed to southwest, force 4, with the barometer at 741.14 mm. For the 24 hours following August 16, 6 a. m., the typhoon moved slowly northward, passing by to the east of Hong Kong late on the night of the 16th. During the forenoon of the 17th it entered the coast of China, between Hong Kong

and Swatow. The wind at Gap Rock backed from east-northeast, force 6, at 5 p. m. on August 15, to north, force 6, at 10 p. m. and north-northwest, force 7, at 7 a. m. August 16, remaining steady from that direction until 3 a. m. August 17, increasing to force 8 at 11 a. m. August 17. Two days after the typhoon had entered China it filled up in the Provinces of Wangtung or Kiangsi.

This depression and typhoon will be memorable for the heavy rains it caused, the rough seas it excited in the China Sea, and the poor visibility it brought in.

A régime of intermittent squalls and abundant rainfall along the western coast of Luzon and in the Visaya Islands began with the typhoon preceding this one and with the low-pressure area over the China Sea out of which this typhoon developed. The winds freshened on August 7 and the following days brought squalls which were most severe at Baler, Maasin, Calbayog, Cebu, and Sorsogon. Strong winds were felt also at Batangas, Corregidor, Manila, and Baguio. Winds of force 7 were reported from Calbayog and Baler on August 10 and from Cebu on August 11, 13, and 15. Force 8 was reported from Calbayog on August 13 and 18. Many other stations reported squalls in which the wind reached force 6. A gale blowing over the China Sea built up high waves that persisted for several days. The U. S. S. *Simpson*, the U. S. S. *Chaumont*, the *Hanover*, the *Anking*, and the *Hinsang*, navigating the eastern part of the China Sea, reported very rough seas, with winds of force 6 to 8. The visibility all over the China Sea was so poor that masters of long experience in the navigation of these seas encountered considerable difficulty in making ports and sighting lighthouses. At the entrance of Corregidor the weather was so thick and the rain so blinding that one end of the ship could not be seen from the other.

The rainfall during this time was heaviest on the western coast of Luzon. Coming simultaneously with the highest tide ever experienced in Manila during the last 26 years, it caused floods in Manila and many low sections of near-by Provinces. The total rainfall in millimeters from August 7 to 15 was 579.9 in Batangas' 793.5 in Dagupan, 886.8 in Iba, and 1,036.5 in Manila. The floods of Manila and adjacent Provinces may afford occasion for another paper, when all the rainfall returns have been received.

The Pacific typhoon of August 11 to 18, 1931.—Almost simultaneously with the formation of the preceding typhoon another one was developing between the Caroline and Marianas Islands. Prescinding from its early indications shown in our weather maps from the 9th to the 11th, and omitting the uncertain movements of the typhoon up to August 14, it was not until the 15th that it had any perceptible effect on the stations in the Loochoos and Bonin Islands and could be definitely situated in about 24° latitude N. and 134° longitude E. It then moved almost west-northwest until the morning of August 16, when it inclined more to the west until the afternoon of the same day, taking afterwards a definite northwest movement until noon of the 17th. Inclining more to the west in the afternoon of August 17, it passed between Naha and Oshima over into the Eastern Sea, where it filled up.

Throughout its course this typhoon remained too far away from our archipelago to have any serious effect on our weather. As far as observations are available at present, nowhere did the barometer fall below 746 mm. under the influence of this typhoon, nor were gales experienced along its path.

The Naha Typhoon, August 14 to 28, 1931.—Probable indications of this typhoon appear in our weather maps of August 14 to 17. Originating between Guam and Yap, it moved very slowly to the north first, but it inclined to the west-northwest at 6 a. m. of the 19th. While swerving more and more to west during the next 48 hours, the barometric minimum deepened, and while the inflow of the air in front of the advancing cyclone was slight, southwesterly winds of force 4 to 6 prevailed from the Strait of San Bernardino down to the northern Mindanao. Under these conditions the U. S. Navy transport *Chaumont*, south of the storm, was fighting its way to Guam against winds of force 7. By this time the last spur of the Pacific high was receding further toward the Pacific, leaving the whole field of the Far East to the typhoon. From 6 a. m. of the 21st to 2 p. m. of the same day the typhoon moved northwest, but inclined successively north-northwest, north, north by east, and back to north until August 23. Changing its course rapidly to the west, the typhoon passed south of and very close to Naha early in the morning of August 24, causing the barometer of Naha to fall at least to 724 mm. Maintaining its westerly motion for 24 hours, the storm inclined to west-northwest, northwest, north-northwest, and north by west, heading for Shanghai.

On the evening of August 25, it struck Ningpo with the full force of a violent gale. After having crossed Hangchow Bay it inclined slightly north by east and instead of devastating Shanghai it passed east of and close to the city at about 3 a. m. on August 26. In the great commercial city, however, and along the Whangpoo River the winds were fierce, and squalls exceeded at times the velocity of 100 miles per hour. Hundreds of trees in the settlement were uprooted or broken. Untold damage was done to roof tops and frail buildings. Flood water piled high by the force of the wind passed the previous high-water record by half a foot and flooded the majority of downtown ground floors in the clubs, banks, and godowns. According to the chief engineer of the Whangpoo Conservancy Board, this excessive water level was due to strong typhoon conditions superimposed on a growing spring tide and the slight rise of the general water levels at Shanghai consequent upon the Yangtze floods. The extraordinary fact that no serious disaster occurred on the water front, in spite of the thousands of small craft and the absence of shelter for both large and small vessels, was attributed both by the harbor officials and the press to the frequent and accurate warnings of Zikawei Observatory.

The *President Cleveland* rode out the storm safely in the river. During the 12 hours following noon, August 25, she was buffeted by winds of force 9 from almost the northeast; from 2 to 4 a. m. on August 26 the wind blew from the north with force 9; from 6 a. m. to 6 p. m. it continued backing from north-northwest, force 8, to west, force 2. The lowest barometer observed on board the *President Cleveland* at 3 a. m. August 26 was 726.90 mm. The press of Shanghai reported 723.90 mm. as the lowest barometric reading during the passage of this storm and compared it with the record barometric minimum 722.40 mm. on August 28, 1915, when the Chinhai typhoon destroyed several Shanghai vessels and exacted a toll of hundreds of lives. After passing Shanghai the typhoon inclined north-northeast, and, gaining speed, it moved decidedly east-northeast or northeast, crossing the Yellow Sea, northern Korea, and the whole Sea of Japan up to La Perousse Strait in 48

hours. The barometer at Nemuro fell to 741 mm. on August 28 at noon with the approach of the storm and rose to 759.5 mm. the next morning at 6 a. m. with the recession of the typhoon toward the Pacific. On the 24th and 25th this typhoon held complete and undivided sway over the whole Far East, the pressure and winds being controlled by it from southern Manchuria down to the Sulu Archipelago, over a distance of at least 2,000 miles. The steamers *President Madison*, *President Cleveland*, U. S. S. *Jason*, and U. S. S. *Parrot* were buffeted by the gales of the typhoon in the Eastern Sea.

The arrival of the *President Cleveland* with the honorable Secretary of War on board was delayed one day on account of the typhoon which the steamer encountered in the Eastern Sea. This typhoon and delay were mentioned in the proclamation of the Governor General of the Philippines transferring from August 31 to September 1 the special public holiday proclaimed on the occasion of the visit of the Secretary of War.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By Giles Slocum

STRAITS OF FLORIDA AND CARIBBEAN SEA

Table 1 shows the average temperatures for the Caribbean Sea and the Straits of Florida for August of each year from 1919 to 1930, inclusive, and Table 2 summarizes the temperature for August, 1930, in the same areas. The chart shows the number of observations taken in August, 1930, within each 1° square and mean temperature data for subdivisions of the areas considered.

For more detailed information regarding the methods of treating data, see the January, 1931, issue of the Monthly Weather Review.

After remaining nearly stationary through much of July, the mean surface temperature of the Caribbean Sea rises throughout August, but at a rate somewhat less marked than during the spring and early summer weeks. In each of the 12 years treated (1919–1930) August has been warmer than July of the same year, and the August 11-year mean temperature (1920–1930) for each of the 5° subdivisions of the Caribbean is higher than that for the same area in July.

August is the warmest month in the Straits of Florida, and there is practically no variation of the mean temperature from one quarter month to the next, the 11-year average for each of the quarters of August being 83.9°.

The local distribution of temperatures remains much the same as in July. The straits are usually warmer than any portion of the Caribbean, the western Caribbean warmer than the eastern, and the northern warmer than the southern except at the eastern extremity.

The differences from east to west are, however, less regularly progressive from lower temperature to higher than in July, and the average temperature is practically at a common level in all portions of the southern Caribbean except in the relatively cool central section.

The August, 1930, temperatures were above average in the Straits of Florida and the northern and extreme eastern Caribbean Sea and close to or below average in the southern Caribbean. The sea as a whole was, for the sixth consecutive month, warmer than the average.

Table 1.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for August, 1919–30*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	87	82.6	20	83.8
1920	157	81.4	47	82.5
1921	280	81.6	91	83.4
1922	192	81.5	70	84.0
1923	315	81.3	87	83.1
1924	318	82.5	121	84.9
1925	494	82.3	116	84.3
1926	491	82.9	142	84.1
1927	592	82.8	211	84.8
1928	566	82.6	166	84.0
1929	716	82.3	205	83.2
1930	589	82.5	153	84.3
Mean (1920–1930)	----------	82.2	----------	83.9

[1] Not used in computations because of insufficient data avilable.

Table 2.—*Mean sea-surface temperatures (°F.) and number of observations, August, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
First	Aug. 1–7	136	82.1	------	------	37	84.2	------	------
Second	Aug. 8–15	143	82.3	------	------	41	84.2	------	------
Third	Aug. 16–23	153	82.8	------	------	38	84.6	------	------
Fourth	Aug. 24–31	157	82.9	------	------	37	84.2	------	------
	Month	589	82.5	+0.3	+0.5	153	84.3	+0.4	+1.3

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, August, 1931

[For description of tables and charts, see Review, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section Average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.9	−1.7	Madison	102	1	Valley Head	47	22	4.66	+0.17	Seale	9.21	Mentone	1.36
Arizona	79.5	−0.4	2 stations	117	[1] 19	Williams	41	[1] 17	4.06	+1.81	Helvetia	11.27	Roll	0.26
Arkansas	76.7	−3.1	Booneville	103	8	Dutton	42	12	4.71	+0.99	Eureka Springs	14.67	Little Rock	1.29
California	74.5	+2.4	Greenland Ranch	123	24	Portola	28	8	0.24	+0.14	Kingston	3.12	97 stations	0.00
Colorado	66.6	+1.2	Cheyenne Wells	107	15	Pearl	17	29	1.37	−0.60	Cope	4.34	Florence	0.22
Florida	81.3	−0.1	Tallahassee	102	4	Garniers	55	24	6.27	−0.73	Marianna	12.57	Long Key	1.56
Georgia	79.0	−0.4	3 stations	104	[1] 2	Clayton	46	[1] 13	5.04	−0.13	Stillmore	12.41	Griffin	1.50
Idaho	68.7	+1.9	Orofino	109	17	Ohsidian	25	27	0.20	−0.45	Grace	2.23	15 stations	0.00
Illinois	74.4	+0.3	White Hall	104	8	Mount Carroll	44	13	3.95	+0.54	Mascoutah	9.37	Aledo	0.81
Indiana	73.8	+0.6	Rome	104	1	2 stations	42	31	4.38	+1.04	Lafayette	7.89	Greencastle	1.86
Iowa	72.6	+0.9	2 stations	102	[1] 4	Decorah	37	30	3.30	−0.14	Lenox	7.18	Sioux Center	1.09
Kansas	76.0	−1.4	Ashland	109	26	Valley Falls	43	12	3.27	+0.17	Valley Falls	12.77	Toronto	0.27
Kentucky	74.9	−0.7	Bowling Green	102	1	Farmers	45	30	5.36	+1.63	Louisa	11.10	Beaver Dam	1.67
Louisiana	79.4	−2.4	2 stations	102	9	3 stations	52	[1] 13	4.91	−0.17	Burrwood	13.79	Arcadia	0.53
Maryland-Delaware	73.8	+0.6	3 stations	101	3	Sines, Md	40	30	7.70	+3.39	Camhridge, Md	14.49	Hancock, Md	3.04
Michigan	68.3	+1.7	Deer Park	104	5	Wolverine	24	31	1.86	−0.81	Bloomingdale	4.51	Ada	0.36
Minnesota	67.7	+0.9	2 stations	104	4	Mahnomen	27	29	2.83	−0.28	Rochester	6.43	Crookston	1.07
Mississippi	78.0	−2.5	Rosedale	100	4	Stoneville	51	14	3.74	−0.60	Biloxi	10.38	University	1.06
Missouri	74.9	−1.1	Chillicothe	106	8	2 stations	44	13	4.77	+1.02	Buffalo	11.00	La Grange	0.54
Montana	67.1	+2.5	Valentine	108	17	Upper Yaak River	18	17	0.48	−0.71	Culhertson (near)	2.19	3 stations	0.00
Nebraska	73.6	+0.7	Purdum	104	14	Gordon	33	29	2.27	−0.55	Geneva	6.75	Hull (near)	0.30
Nevada	73.3	+3.1	Las Vegas	115	24	Zorra Vista Ranch	28	8	0.86	+0.33	Searchlight	6.30	3 stations	0.00
New England	67.6	+0.8	Turner's Falls, Mass.	99	6	Somerset, Vt	33	26	4.12	+0.24	West Rutland, Mass	10.78	Bethel, Vt	1.43
New Jersey	73.5	+1.5	3 stations	101	[1] 3	Charlottehurg	45	25	5.10	+0.36	Bridgeton	9.61	Phillipshurg	2.26
New Mexico	69.3	−0.9	2 stations	106	27	Therma (near)	26	25	3.07	+0.51	Cloudcroft	9.69	Albuquerque	0.23
New York	68.6	+1.3	West Point	105	7	Gahriels	33	26	3.05	−0.77	Bridgehampton	6.28	Ogdensburg	0.86
North Carolina	75.0	−0.8	2 stations	101	[1] 3	Mount Mitchell	38	23	7.52	+1.96	Red Springs	15.73	Cullowhee	2.57
North Dakota	67.0	+0.8	McLeod	105	4	Pemhina	30	[1] 30	2.09	+0.05	Cando	4.95	Alpha	0.36
Ohio	72.7	+1.1	Vickery	103	7	2 stations	38	31	4.99	+1.65	Peebles	9.33	Wauseon	1.37
Oklahoma	79.2	−1.9	Buffalo	108	26	Hooker	43	29	2.79	−0.42	Claremore	9.01	Chattanooga	0.40
Oregon	66.4	+1.4	Umatilla	108	[1] 1	Seneca	19	[1] 26	0.02	−0.40	Crossett	0.48	52 stations	0.00
Pennsylvania	71.1	+1.1	Holtwood	104	8	2 stations	40	[1] 22	4.01	−0.16	Kregar	8.78	Franklin	1.30
South Carolina	78.2	−0.6	Cheraw	105	2	Caesars Head	50	[1] 13	4.84	−0.89	Marion	10.45	2 stations	1.84
South Dakota	72.5	+2.2	2 stations	108	[1] 4	Milbank	34	30	1.61	−0.79	Armour	5.63	Hardy Ranger Station.	0.20
Tennessee	75.5	−0.9	do	101	[1] 1	Crossville	41	23	4.67	+0.66	Elkmont	14.26	Palmetto	1.09
Texas	81.1	−1.7	Fort Stockton	107	27	Spearman	48	29	2.04	−0.40	Eagle Pass	7.17	4 stations	0.00
Utah	71.6	+2.0	St. George	109	[1] 24	Coalville	28	27	0.75	−0.31	Yellowstone Ranger Station.	2.20	Fort Duchesne	T.
Virginia	73.8	+0.1	Lincoln	102	8	Dale Enterprise	41	27	6.68	+2.30	Randolph	11.79	Winchester	2.81
Washington	65.8	0.0	2 stations	107	[1] 1	3 stations	31	[1] 7	0.16	−0.68	Palmer (near)	1.63	37 stations	0.00
West Virginia	71.6	+0.2	Charleston	102	2	2 stations	39	30	6.38	+2.22	Pickens	10.63	Kearneysville	1.62
Wisconsin	67.8	+0.7	7 stations	100	[1] 5	Coddington	26	30	2.74	−0.62	Mondovi	5.25	Appelton	1.10
Wyoming	65.0	+1.1	2 stations	103	[1] 4	Riverside	20	28	0.93	−0.20	Pathfinder	2.87	Eden	0.00
Alaska (July)	54.2	−1.8	do	84	[1] 2	Dillingham	27	9	2.40	−0.31	Mile Seven (Cordova).	11.47	St. Paul Island	0.32
Hawaii	75.6	+0.6	Waipahu	94	25	Kanalohuluhulu	49	29	8.12	+1.60	Hiloa - Manawaiopuna Divide.	48.00	Reservoir No. 8	0.06
Porto Rico	79.8	+0.7	2 stations	98	29	Guineo Reservoir	55	24	6.64	−1.42	Rio Blanco	14.33	Ponce	2.72

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1931*

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							68.8	+1.4										81	3.71	+0.1										5.8		
Eastport	76	67	85	29.93	30.01	+0.05	62.2	+1.5	82	6	70	50	30	54	26	59	57	85	4.11	+1.1	16	4,293	s.	26	e.	12	4	9	18	7.4	0.0	0.0
Greenville, Me.	1,070	6	----	28.88	30.03	------	62.4	------	87	6	72	39	27	53	34	58	----	85	3.77	------	15	3,103	nw.	15	------	8	8	10	13	----	0.0	0.0
Portland, Me.	103	82	117	29.90	30.02	+.04	68.0	+1.6	98	6	75	54	2	60	34	61	57	74	3.41	+0.3	15	4,220	n.	22	nw.	6	16	5	10	5.0	0.0	0.0
Concord	289	70	79	29.72	30.02	+.04	67.6	+0.8	95	6	78	46	2	57	36	----	----	----	4.03	+0.5	12	2,415	n.	15	nw.	3	12	9	10	5.6	0.0	0.0
Burlington	403	11	48	29.59	30.02	+.05	66.6	−1.3	93	6	76	48	2	57	28	----	----	----	1.84	−1.5	12	4,152	s.	27	nw.	6	7	14	10	5.7	0.0	0.0
Northfield	876	12	60	------	30.05	+.07	62.6	−0.8	91	6	75	40	22	50	34	----	----	86	2.01	−1.5	12	3,230	s.	18	sw.	30	3	19	9	6.3	0.0	0.0
Boston	125	106	165	29.88	30.02	+.03	72.2	+2.3	97	6	80	58	25	65	25	64	61	74	4.45	+0.8	12	4,327	nw.	18	ne.	24	7	12	12	5.9	0.0	0.0
Nantucket	12	14	90	30.00	30.01	+.02	70.6	+2.8	86	7	77	60	2	64	18	66	65	87	3.49	+0.1	9	8,792	sw.	48	ne.	24	9	10	12	5.5	0.0	0.0
Block Island	26	11	46	29.98	30.01	+.02	71.0	+2.5	87	7	76	59	25	66	18	66	65	86	4.72	+1.0	11	8,858	sw.	36	nw.	17	9	10	12	5.9	0.0	0.0
Providence	160	215	251	29.85	30.02	+.03	72.2	+1.2	95	7	80	56	2	64	26	66	64	80	4.99	+1.5	13	5,916	nw.	34	nw.	3	11	7	13	5.3	0.0	0.0
Hartford	159	122	----	29.85	30.02	+.03	71.8	+2.9	95	7	80	53	25	63	29	----	----	----	4.45	+0.2	9	------	sw.	----	------	----	8	7	16	6.0	0.0	0.0
New Haven	106	74	153	29.90	30.02	+.03	72.8	+2.5	96	7	81	55	25	65	26	66	63	76	3.31	−1.0	10	4,966	n.	22	sw.	30	9	12	10	5.8	0.0	0.0
Middle Atlantic States							74.1	+0.7										78	5.27	+1.0										6.0		
Albany	97	107	115	29.92	30.02	+.04	71.0	+0.2	96	6	80	54	2	62	29	64	61	76	2.34	−1.4	10	3,847	s.	25	n.	17	10	13	8	5.0	0.0	0.0
Binghamton	871	10	84	29.12	30.04	+.05	69.9	+1.9	92	6	80	50	31	60	32	----	----	----	2.86	−0.7	9	2,728	ne.	18	w.	30	4	7	20	7.3	0.0	0.0
New York	314	414	454	29.68	30.00	.00	74.4	+1.3	93	7	81	61	24	68	20	66	63	73	3.26	−1.1	13	6,837	ne.	40	nw.	3	7	9	15	6.4	0.0	0.0
Bellefonte	1,050	5	36	28.94	30.03	------	68.4	------	92	7	80	45	31	57	35	63	61	81	2.80	------	9	------	sw.	----	------	----	6	8	17	7.0	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	.00	73.8	+1.2	96	6	82	58	31	66	30	66	62	73	3.18	−0.9	13	3,330	w.	33	sw.	9	7	13	11	5.9	0.0	0.0
Philadelphia	114	123	367	29.90	30.02	+.02	76.3	+1.5	98	7	84	60	23	69	22	68	64	71	6.00	+1.4	16	7,450	sw.	36	n.	23	9	9	13	6.2	0.0	0.0
Reading	325	81	98	29.68	30.02	------	74.2	+1.8	96	6	83	58	24	70	28	66	63	72	4.72	+0.5	12	2,910	sw.	31	ne.	10	8	6	17	6.6	0.0	0.0
Scranton	805	111	119	29.19	30.04	+.04	71.2	+1.4	95	7	81	51	31	61	33	64	61	75	1.90	−1.8	12	3,348	sw.	18	sw.	30	7	14	10	5.8	0.0	0.0
Atlantic City	52	37	172	29.95	30.00	.00	74.5	+2.0	91	17	80	61	24	69	22	69	67	82	7.21	+2.7	11	10,194	s.	56	ne.	23	8	11	12	5.7	0.0	0.0
Cape May	17	13	49	------	------	------	74.0	+0.6	88	6	80	60	22	68	19	69	68	85	6.97	+2.7	11	------	s.	----	------	----	6	13	12	----	0.0	0.0
Sandy Hook	22	10	55	29.98	30.00	------	74.3	------	96	7	80	61	23	68	22	68	66	82	5.26	+0.3	13	7,746	sw.	38	ne.	11	5	10	16	6.5	0.0	0.0
Trenton	190	159	183	29.82	30.02	------	74.0	+1.0	96	7	82	58	23	66	26	67	64	76	6.39	+1.6	14	5,414	sw.	31	nw.	10	7	9	15	6.5	0.0	0.0
Baltimore	123	100	215	29.88	30.01	.00	77.0	+1.6	100	3	84	58	23	70	23	68	64	70	7.98	+3.6	19	5,703	sw.	30	sw.	3	8	11	12	5.9	0.0	0.0
Washington	112	62	85	29.90	30.01	.00	75.6	+0.6	98	3	84	56	22	67	27	68	65	76	5.92	+1.9	18	3,295	sw.	30	sw.	18	9	9	13	5.9	0.0	0.0
Cape Henry	18	8	54	29.99	30.01	------	77.2	+0.3	96	10	84	63	25	70	24	72	70	82	6.14	+1.3	15	6,560	sw.	38	ne.	22	10	13	8	5.3	0.0	0.0
Lynchburg	681	153	188	29.31	30.04	+.02	74.6	−1.0	96	4	84	55	30	65	28	67	65	78	5.16	+1.4	17	3,155	w.	26	nw.	2	10	16	5	5.0	0.0	0.0
Norfolk	91	170	205	29.93	30.03	+.03	77.8	+0.4	97	4	86	61	23	70	24	70	68	79	4.25	−1.0	14	6,528	sw.	68	nw.	19	11	10	10	5.7	0.0	0.0
Richmond	144	11	52	29.88	30.03	+.02	75.7	−0.8	95	3	84	58	24	67	26	70	68	86	11.42	+7.0	15	3,862	sw.	25	nw.	27	6	11	14	6.1	0.0	0.0
Wytheville	2,304	49	55	27.73	30.05	+.04	68.8	−1.7	87	2	79	48	30	58	31	63	62	84	3.83	−0.4	17	2,866	w.	21	w.	28	5	15	11	6.0	0.0	0.0
South Atlantic States							78.2	+0.1										81	5.23	−0.4										5.6		
Asheville	2,253	89	104	27.77	30.06	+.04	72.0	+1.5	92	1	83	50	24	61	34	64	63	85	4.01	−0.2	19	3,028	nw.	19	nw.	12	3	23	5	5.7	0.0	0.0
Charlotte	779	55	62	29.23	30.05	+.03	77.2	+0.1	96	1	87	58	23	68	26	69	67	82	8.13	+3.1	14	2,217	s.	18	nw.	20	7	12	12	5.9	0.0	0.0
Greensboro	886	6	56	29.12	30.06	------	73.8	------	92	4	83	51	24	64	29	68	67	89	10.29	------	16	3,864	sw.	30	w.	2	5	15	11	6.2	0.0	0.0
Hatteras	11	5	50	30.02	30.03	+.04	78.0	0.0	89	17	85	65	24	72	20	74	72	83	6.14	+0.4	13	6,508	sw.	32	nw.	29	12	13	6	4.6	0.0	0.0
Raleigh	376	103	146	29.65	30.03	+.02	76.2	−0.8	95	10	85	57	23	68	26	70	68	82	9.54	+4.1	16	3,998	sw.	39	nw.	2	6	16	9	6.4	0.0	0.0
Wilmington	78	81	91	29.98	30.06	+.06	78.5	+0.9	94	2	86	61	24	70	23	73	71	86	5.53	−0.8	16	3,545	sw.	19	w.	14	12	12	7	4.9	0.0	0.0
Charleston	48	11	92	30.01	30.06	+.05	80.0	−1.0	91	4	87	63	24	73	22	74	73	82	4.93	−1.6	13	5,738	sw.	28	se.	13	9	14	8	5.5	0.0	0.0
Columbia, S. C.	351	41	57	29.68	30.05	+.04	79.2	−0.2	96	2	89	58	24	70	26	71	68	77	2.20	−3.3	10	3,589	sw.	23	sw.	10	9	16	6	5.2	0.0	0.0
Due West	711	10	55	29.31	30.07	------	77.4	------	97	3	87	57	13	68	28	----	----	----	3.88	------	14	3,941	sw.	27	w.	6	4	16	11	6.0	0.0	0.0
Greenville, S. C.	1,039	139	146	28.97	30.05	------	76.8	+1.0	96	4	86	57	13	68	25	68	66	76	4.46	−1.0	12	4,023	ne.	38	sw.	12	6	19	6	5.4	0.0	0.0
Augusta	182	62	77	29.84	30.03	+.02	80.2	−0.2	101	3	90	59	24	70	28	72	69	77	4.54	−0.5	11	2,760	s.	21	nw.	5	5	17	9	5.5	0.0	0.0
Savannah	65	150	194	29.98	30.05	+.04	81.2	+0.4	97	5	90	62	24	72	25	73	71	81	3.23	−4.1	8	6,259	w.	37	w.	10	8	13	10	5.7	0.0	0.0
Jacksonville	43	209	245	30.02	30.07	+.06	80.8	−0.9	94	5	88	60	25	73	21	73	71	79	4.86	−1.0	13	6,559	s.	33	s.	4	7	14	10	6.0	0.0	0.0
Florida Peninsula							83.0	+0.9										78	5.64	−0.7										6.1		
Key West	22	10	64	30.01	30.03	+.05	83.8	+0.3	92	12	90	71	17	78	17	78	77	79	5.56	+1.0	14	4,940	e.	29	se.	14	9	13	9	5.5	0.0	0.0
Miami	25	124	168	30.03	30.06	+.03	83.0	+1.6	91	22	89	73	28	77	17	77	74	75	5.02	−1.2	10	5,370	e.	26	n.	24	2	16	13	6.5	0.0	0.0
Tampa	35	79	197	30.03	30.06	+.06	82.2	+0.7	94	5	90	69	12	74	22	75	73	81	6.35	−1.8	14	5,619	e.	38	ne.	27	0	20	11	6.6	0.0	0.0
Titusville	44	5	----	30.03	30.08	------	82.9	------	100	5	92	70	8	74	27	----	----	----	4.90	------	14	------	se.	----	------	----	6	16	9	5.9	0.0	0.0
East Gulf States							78.8	−1.2										77	5.96	+0.7										5.6		
Atlanta	1,173	190	198	28.85	30.06	+.05	77.0	0.0	94	3	86	57	23	68	23	67	63	69	2.44	−2.0	9	5,129	w.	23	nw.	22	10	14	7	5.0	0.0	0.0
Macon	370	78	87	29.67	30.06	+.05	79.0	−0.9	100	5	89	59	24	69	29	70	68	76	7.31	+3.0	12	3,175	sw.	25	w.	27	11	7	13	5.6	0.0	0.0
Thomasville	273	49	103	29.77	30.06	+.06	79.2	−0.8	97	4	88	63	24	70	24	72	70	80	6.89	+1.1	14	3,567	sw.	22	nw.	27	2	13	16	7.1	0.0	0.0
Apalachicola	36	11	51	30.02	30.06	------	80.3	------	93	4	87	68	13	74	20	74	72	78	11.74	+4.2	14	4,112	w.	30	se.	14	8	8	15	6.4	0.0	0.0
Pensacola	56	149	185	30.00	30.07	+.09	78.9	−2.0	90	4	84	65	12	73	17	72	70	77	8.66	+0.6	10	6,715	sw.	42	s.	10	3	22	6	5.8	0.0	0.0
Anniston	741	9	57	------	------	------	76.6	+0.2	96	3	88	53	23	65	34	----	----	----	2.81	−1.2	8	2,129	nw.	15	nw.	21	10	13	8	----	0.0	0.0
Birmingham	700	11	48	29.32	30.08	+.09	77.8	−1.4	95	5	88	58	12	67	28	69	66	78	4.69	+0.4	13	2,809	n.	25	se.	19	10	11	10	5.3	0.0	0.0
Mobile	57	125	161	30.01	30.07	+.09	79.6	−1.4	94	4	88	64	12	72	22	72	70	80	5.84	−1.1	9	4,846	n.	38	nw.	10	4	16	11	6.4	0.0	0.0
Montgomery	223	100	112	29.82	30.07	+.08	79.6	−1.2	96	1	89	63	24	70	27	70	67	75	4.07	−0.2	10	3,503	sw.	30	n.	10	11	11	9	5.5	0.0	0.0
Corinth	469	6	----	------	------	------	77.4	------	98	1	88	56	13	66	33	----	----	----	5.90	------	11	------	sw.	----	------	----	7	20	4	----	0.0	0.0
Meridian	375	87	95	29.68	30.06	+.08	77.8	−1.7	93	1	88	60	23	68	29	70	68	77	8.79	+4.2	10	2,925	sw.	18	nw.	10	11	13	7	4.9	0.0	0.0
Vicksburg	247	65	73	29.81	30.09	+.11	78.2	−2.6	93	31	87	61	12	69	24	70	68	77	2.99	−0.5	7	3,611	sw.	29	nw.	20	12	12	7	4.4	0.0	0.0
New Orleans	53	76	84	30.01	30.06	+.08	81.2	−1.0	94	8	88	69	26	74	21	73	71	76	5.28	−0.5	13	3,454	so.	17	ne.	15	6	19	6	5.2	0.0	0.0
West Gulf States							80.7	−1.2										72	2.75	−0.3										4.2		
Shreveport	249	204	220	29.78	30.04	+.07	80.3	−1.7	96	1	90	64	12	71	24	70	67	72	3.96	+1.3	6	5,618	s.	35	n.	28	13	15	3	4.2	0.0	0.0
Bentonville	1,303	11	44	28.69	30.04	+.07	73.9	−2.6	92	7	84	53	12	64	32	----	----	----	5.68	------	12	2,427	s.	17	sw.	9	24	6	1	----	0.0	0.0
Fort Smith	457	79	94	29.55	30.02	+.05	78.0	−2.5	98	9	87	59	29	68	27	70	66	74	8.71	+5.4	11	3,899	e.	25	n.	28	10	13	8	5.3	0.0	0.0
Little Rock	357	136	153	29.68	30.05	+.07	77.8	−2.0	94	7	87	62	14	69	25	69	66	73	1.29	−2.5	10	4,754	sw.	24	sw.	17	9	7	15	6.0	0.0	0.0
Austin	605	136	148	29.38	30.01	------	83.1	−0.7	98	20	94	64	13	72	32	71	67	67	1.85	−0.2	4	4,868	s.	28	n.	21	15	16	0	3.6	0.0	0.0
Brownsville	57	83	100	29.94	30.00	------	82.0	−1.9	92	21	90	66	17	74	23	74	72	80	2.23	−0.3	7	6,155	se.	25	se.	26	15	13	3	3.7	0.0	0.0
Corpus Christi	20	11	78	30.00	30.02	+.09	82.4	−0.1	94	20	89	70	13	76	19	75	73	80	1.54	−0.7	8	6,909	se.	25	e.	23	13	13	5	4.4	0.0	0.0
Dallas	512	220	227	29.48	30.03	------	81.6	------	98	9	91	66	12	72	25	----	----	----	1.23	−1.5	4	7,727	s.	32	n.	28	17	14	0	3.1	0.0	0.0
Fort Worth	670	106	114	29.29	29.99	+.05	82.6	−0.4	99	9	93	62	12	72	29	69	62	57	3.38	+0.8	4	5,936	s.	23	sw.	9	9	20	2	4.4	0.0	0.0
Galveston	54	106	114	30.00	30.06	+.10	82.2	−0.8	91	10	87	70	16	78	16	75	72	75	4.23	0.0	14	6,014	s.	21	sw.	26	10	13	8	4.6	0.0	0.0
Houston	138	292	314	29.90	30.04	------	82.0	−1.2	97	10	90	64	16	74	27	----	----	----	3.62	−0.5	6	6,529	s.	31	se.	19	12	16	3	4.2	0.0	0.0
Palestine	510	64	72	29.52	30.04	+.07	80.2	−1.6	94	9	90	61	15	70	26	70	67	72	3.13	+1.0	8	4,269	s.	28	ne.	29	17	11	3	3.5	0.0	0.0
Port Arthur	34	58	66	30.00	30.04	------	81.8	------	97	10	89	64	15	74	27	74	71	77	3.06	−3.0	14	4,409	s.	28	n.	15	14	7	10	4.8	0.0	0.0
San Antonio	693	242	301	29.29	29.99	+.06	82.0	−1.5	96	10	92	68	16	72	25	72	68	68	0.30	−2.1	3	7,040	se.	31	s.	20	14	16	1	3.9	0.0	0.0
Taylor	571	38	51	29.46	30.06	+.11	82.8	+1.1	99	10	94	63	12	71	30	----	----	----	0.03	−2.4	1	5,353	s.	23	s.	20	19	10	2	2.7	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							74.5	−0.4										74	3.87	+0.4										5.8		
Chattanooga	762	190	215	29.24	30.04	+0.04	76.9	−0.6	95	3	86	56	13	67	30	68	64	70	2.67	−1.4	11	4,130	sw.	25	nw.	12	7	20	4	5.5	0.0	0.0
Knoxville	995	102	111	29.02	30.06	+.05	76.0	−0.2	96	3	86	56	13	66	31	68	65	76	3.40	−0.5	13	3,123	sw.	20	n.	1	4	18	9	5.8	0.0	0.0
Memphis	399	76	97	29.63	30.05	+.07	77.4	−2.0	92	7	85	60	12	70	20	70	66	74	2.25	−1.1	10	4,703	sw.	20	w.	19	11	10	10	5.0	0.0	0.0
Nashville	546	168	191	29.49	30.07	+.07	76.4	−1.4	96	1	86	57	13	67	31	68	65	74	3.94	+0.2	11	4,431	w.	26	nw.	20	9	12	10	5.7	0.0	0.0
Lexington	989	193	230	29.03	30.07	+.06	74.2	−0.3	92	1	82	58	12	66	23	----	----	----	2.40	−1.0	11	6,481	sw.	29	nw.	3	8	15	8	5.5	0.0	0.0
Louisville	525	188	234	29.48	30.06	+.06	75.9	−1.1	96	2	84	59	22	68	25	68	64	73	2.91	−0.5	13	5,440	s.	40	nw.	9	4	11	16	6.5	0.0	0.0
Evansville	431	76	116	29.58	30.04	+.05	76.4	−1.0	97	1	86	58	12	67	27	68	65	73	6.27	+2.9	11	4,669	sw.	37	s.	3	9	11	11	5.4	0.0	0.0
Indianapolis	822	194	230	29.16	30.03	+.03	74.6	+0.9	95	1	84	56	29	66	24	65	60	67	4.70	+1.4	12	5,714	sw.	28	nw.	29	11	14	6	5.0	0.0	0.0
Royal Center	736	11	55	29.26	30.04	------	71.6	------	93	1	83	51	12	61	31				3.94	+1.4	10	4,319	sw.	32	nw.	27	12	13	6	4.5	0.0	0.0
Terre Haute	575	96	129	29.42	30.03	------	75.0	------	96	1	85	56	12	65	28	66	62	71	3.69	+0.4	10	4,778	n.	31	sw.	2	9	14	8	5.2	0.0	0.0
Cincinnati	627	11	51	29.38	30.05	+.04	74.4	+0.8	96	1	84	56	23	65	26	67	64	77	4.24	+0.8	15	3,382	sw.	24	nw.	3	8	11	12	6.1	0.0	0.0
Columbus	822	216	230	29.17	30.03	+.02	72.8	−0.2	92	2	81	55	30	65	25	66	62	73	4.80	+1.5	14	4,802	s.	32	s.	28	6	14	11	6.2	0.0	0.0
Dayton	899	137	173	29.10	30.03	------	73.6	+0.2	94	1	82	55	23	65	26	66	62	72	2.27	−1.0	11	4,165	sw.	24	sw.	28	8	16	7	5.5	0.0	0.0
Elkins	1,947	59	67	28.08	30.08	+.06	68.2	−0.9	90	2	79	44	30	58	32	62	60	86	6.33	+2.5	15	2,243	w.	22	nw.	28	3	13	15	6.9	0.0	0.0
Parkersburg	637	77	82	29.42	30.07	+.06	73.8	−0.1	97	8	83	53	30	64	30	66	64	80	4.70	+1.2	15	2,788	se.	20	nw.	10	7	8	16	6.7	0.0	0.0
Pittsburgh	842	353	410	29.15	30.04	+.03	73.0	+0.1	94	8	82	55	31	64	25	65	61	72	3.50	+0.3	11	4,838	sw.	26	n.	10	5	11	15	6.9	0.0	0.0
Lower Lake Region							71.3	+1.7										69	2.41	−0.6										5.5		
Buffalo	767	247	280	29.19	30.01	+.02	70.2	+1.6	86	2	77	55	31	64	25	63	59	72	2.58	−0.5	12	8,791	sw.	50	sw.	29	9	11	11	5.7	0.0	0.0
Canton	448	10	61	29.53	30.00	------	66.4	−1.4	90	6	77	46	31	56	33				1.51	−2.1	11	4,205	sw.	35	w.	18	8	15	8	5.1	0.0	0.0
Ithaca	836	74	100	29.13	30.02	------	70.6	+2.0	98	6	82	45	31	59	35	62	59	71	1.30	−2.1	9	4,151	nw.	18	s.	9	8	13	10	6.0	0.0	0.0
Oswego	335	71	85	29.65	30.02	+.03	69.6	+1.2	93	6	77	52	31	62	25	63	59	69	1.26	−1.3	8	4,883	n.	21	n.	19	8	11	12	5.9	0.0	0.0
Rochester	523	86	102	29.48	30.04	+.05	70.8	+1.6	95	6	79	51	31	63	28	63	58	67	1.84	−1.0	7	4,358	ne.	26	w.	29	8	11	12	5.8	0.0	0.0
Syracuse	596	65	79	29.40	30.03	+.04	71.0	+2.4	94	6	80	51	31	62	26	----	----	----	1.91	−1.0	6	3,320	s.	19	nw.	3	4	12	15	6.9	0.0	0.0
Erie	714	130	166	29.27	30.02	+.01	71.6	+2.0	92	6	79	53	31	64	23	66	64	78	1.78	−1.5	12	7,177	sw.	34	sw.	29	10	15	6	4.7	0.0	0.0
Cleveland	762	267	337	29.21	30.02	+.01	72.3	+2.3	94	2	79	56	31	66	22	64	59	65	2.75	0.0	14	7,087	sw.	35	n.	21	9	7	15	5.9	0.0	0.0
Sandusky	629	5	67	29.36	30.03	+.02	73.9	+2.1	98	2	82	48	31	65	29	----	----	----	6.39	+3.2	16	4,412	sw.	20	sw.	29	6	14	11	5.8	0.0	0.0
Toledo	628	208	243	29.36	30.03	+.03	73.2	+1.9	97	7	82	50	31	65	25	64	59	66	2.82	0.0	12	7,266	sw.	37	w.	29	15	9	7	4.5	0.0	0.0
Fort Wayne	856	100	119	29.12	30.03	------	73.0	+1.9	94	5	82	53	31	64	29	64	60	69	3.97	+0.9	16	4,326	sw.	28	se.	28	11	13	7	5.1	0.0	0.0
Detroit	730	218	258	29.26	30.04	+.03	73.2	+2.9	97	6	82	52	31	65	23	63	58	65	0.84	−1.9	8	6,002	sw.	33	sw.	29	7	17	7	5.1	0.0	0.0
Upper Lake Region							67.9	+1.7										70	2.05	−0.8										4.9		
Alpena	609	13	92	29.38	30.05	+.05	66.4	+2.3	90	17	75	40	31	57	30	60	56	72	1.75	−1.1	10	6,416	se.	25	se.	8	14	7	10	4.8	0.0	0.0
Escanaba	612	54	60	29.38	30.04	+.05	64.7	+0.4	93	5	73	41	30	56	26	59	55	73	1.25	−1.9	10	5,901	s.	26	n.	10	12	10	9	4.7	0.0	0.0
Grand Haven	632	54	89	29.35	30.02	+.03	69.1	+2.0	89	6	78	45	31	60	33	62	57	67	0.71	−2.2	8	6,477	sw.	32	nw.	29	15	7	9	4.6	0.0	0.0
Grand Rapids	707	70	244	29.27	30.03	+.03	72.4	+2.7	98	6	83	48	31	62	33	61	55	60	0.72	−1.9	6	6,948	sw.	36	w.	28	9	10	12	5.3	0.0	0.0
Houghton	668	64	99	29.30	30.02	+.05	64.5	+0.8	92	4	74	42	31	56	28	----	----	----	1.98	−0.7	7	6,521	w.	41	n.	17	9	11	11	5.6	T.	0.0
Lansing	878	6	88	29.10	30.02	------	69.8	+1.3	94	2	81	41	31	58	35	62	58	72	1.70	−1.1	7	4,593	sw.	27	sw.	29	9	16	6	4.8	0.0	0.0
Ludington	637	60	66	29.34	30.03	------	67.3	+2.0	88	17	75	43	31	60	27	61	57	71	2.06	−0.6	9	6,275	n.	31	w.	29	18	7	6	3.3	0.0	0.0
Marquette	734	77	111	29.23	30.02	+.04	65.4	+1.5	99	5	73	46	31	58	32	58	54	70	1.03	−1.6	6	6,183	w.	27	w.	29	9	5	17	6.2	0.0	0.0
Port Huron	638	70	120	29.34	30.02	+.02	70.8	+3.0	94	2	79	46	31	63	31	62	58	69	1.40	−1.3	12	6,314	n.	30	w.	29	7	17	7	5.2	0.0	0.0
Sault Sainte Marie	614	11	52	29.35	30.04	+.05	64.4	+2.3	94	5	74	40	31	55	34	57	53	73	1.80	−0.8	11	4,390	nw.	23	sw.	28	12	11	8	5.0	0.0	0.0
Chicago	673	7	131	29.27	30.04	+.04	73.2	+1.6	93	8	81	55	29	66	27	64	60	68	5.67	+2.5	9	6,050	ne.	27	nw.	27	14	12	5	3.8	0.0	0.0
Green Bay	617	109	141	29.37	30.02	+.03	68.2	+0.5	97	5	78	43	30	59	31	60	55	67	2.34	−0.8	11	6,502	n.	28	w.	29	8	10	13	6.2	0.0	0.0
Milwaukee	681	125	221	29.30	30.04	+.04	71.8	+2.6	94	4	79	52	30	64	25	63	59	69	1.96	−0.7	8	7,988	w.	48	ne.	27	10	13	8	4.8	0.0	0.0
Duluth	1,133	5	47	28.80	30.00	+.03	63.9	+1.3	92	5	73	39	30	55	29	57	54	76	4.32	+1.1	9	7,131	ne.	32	w.	29	10	10	11	5.3	0.0	0.0
North Dakota							67.6	+1.5										65	2.11	−0.2										5.2		
Moorhead	940	50	58	28.98	29.98	+.02	67.6	+1.5	102	4	79	36	30	56	42	59	53	66	1.85	−1.0	6	5,373	s.	33	nw.	28	7	11	13	6.3	0.0	0.0
Bismarck	1,674	8	57	28.23	29.99	+.05	67.5	+0.2	99	4	79	45	30	56	36	59	53	67	1.58	−0.2	8	5,764	s.	31	n.	22	13	12	6	4.6	0.0	0.0
Devils Lake	1,478	11	44	28.43	29.98	+.04	66.2	+1.4	100	4	78	40	30	54	36	57	52	67	3.89	+1.4	8	5,972	nw.	30	nw.	28	9	11	11	5.8	0.0	0.0
Ellendale	1,457	10	56	28.45	30.00	------	68.0	------	101	4	81	40	30	55	45	----	----	----	2.15	−0.9	9	8,412	nw.	37	nw.	28	11	12	8	5.2	0.0	0.0
Grand Forks	833	12	67				67.8	------	102	4	79	36	30	56	42	58	----	----	2.01		8		se.	40	nw.	28	13	12	6	----	0.0	0.0
Williston	1,878	41	48	28.02	29.96	+.03	69.0	+2.9	96	21	81	41	28	57	39	58	51	60	1.10	−0.4	4	5,011	se.	39	nw.	7	15	10	6	3.9	0.0	0.0
Upper Mississippi Valley							73.4	+0.7										67	3.39	+0.1										5.0		
Minneapolis	918	102	208	29.02	29.98	------	70.6	+0.7	99	4	80	46	30	61	29	----	----	----	2.97	−0.2	8	6,696	s.	36	w.	28	6	11	14	6.5	0.0	0.0
St. Paul	837	114	149	29.12	30.01	+.04	70.5	+1.1	97	4	81	43	30	60	30	----	----	----	3.45	+0.4	11	5,195	sw.	26	nw.	28	9	9	13	5.5	0.0	0.0
La Crosse	714	11	48	29.25	30.01	+.03	71.0	+1.0	97	4	83	40	30	59	35	61	57	68	2.29	−1.4	9	2,407	s.	25	e.	27	15	5	11	4.8	0.0	0.0
Madison	974	70	78	29.00	30.02	+.03	70.8	+1.0	92	4	83	48	30	61	29	62	56	64	5.19	+2.0	8	4,708	sw.	31	e.	27	12	8	11	5.2	0.0	0.0
Wausau	1,247	4	62	28.73	30.04	------	66.8	------	97	5	79	39	30	55	40				2.67	−0.9	10	3,681	n.	24	w.	29	14	10	7	4.4	0.0	0.0
Charles City	1,015	10	51	28.97	30.03	+.06	72.0	+2.9	96	16	84	44	30	60	37	61	55	61	3.55	+0.1	6	3,662	se.	20	nw.	27	14	10	7	4.3	0.0	0.0
Davenport	606	71	79	29.38	30.03	+.05	74.6	+1.5	97	8	85	54	12	64	28	63	57	62	3.16	−0.3	8	4,785	ne.	48	sw.	27	10	11	10	5.3	0.0	0.0
Des Moines	861	5	99	29.13	30.02	+.05	72.6	−0.5	92	6	84	50	29	62	34	64	59	67	3.66	+0.1	13	4,873	s.	29	w.	28	11	11	9	5.2	0.0	0.0
Dubuque	700	81	96	29.28	30.02	+.04	73.1	+1.4	94	4	84	51	12	62	31	62	56	60	2.02	−1.2	5	3,184	sw.	25	nw.	27	9	7	15	5.9	0.0	0.0
Keokuk	614	64	78	29.38	30.05	+.07	74.6	−0.4	100	8	85	54	12	64	30	65	60	65	2.40	−0.8	9	3,485	sw.	22	w.	28	12	9	10	4.8	0.0	0.0
Cairo	358	87	93	29.66	30.03	+.04	76.2	−1.6	92	1	84	59	13	68	23	69	66	78	7.14	+4.1	9	4,403	s.	26	n.	11	7	8	16	6.1	0.0	0.0
Peoria	609	11	45	29.39	30.05	+.06	74.0	+1.5	98	8	85	50	13	62	32	65	61	71	2.49	−0.6	7	2,564	ne.	16	nw.	27	17	9	5	3.6	0.0	0.0
Springfield, Ill	636	5	191	29.36	30.02	+.03	75.6	+1.1	100	8	86	55	29	65	28	66	62	70	3.58	+0.4	6	5,983	n.	27	sw.	27	8	14	9	5.4	0.0	0.0
Hannibal	534	74	109	29.47	30.04	+.06	75.0	0.0	100	8	85	53	13	65	30	----	----	----	2.71	−0.6	7	3,916	sw.	24	w.	28	14	9	8	4.5	0.0	0.0
St. Louis	568	265	303	29.43	30.03	+.04	77.2	−0.1	100	8	86	58	12	68	27	67	63	68	3.46	+0.5	11	5,608	s.	33	nw.	2	16	9	6	3.9	0.0	0.0
Missouri Valley							74.7	+0.8										63	4.22	+5.3										4.5		
Columbia, Mo	784	6	84	29.21	30.03	+.06	75.0	−0.6	98	7	86	53	13	65	31	----	----	----	8.86	+1.0	10	3,520	sw.	31	nw.	31	13	10	8	4.7	0.0	0.0
Kansas City	963	161	181	29.02	30.03	+.06	76.0	−0.6	97	7	85	56	11	67	27	66	62	66	3.45	−0.6	9	4,780	se.	27	n.	9	13	12	6	4.4	0.0	0.0
St. Joseph	967	11	49	29.00	30.01	------	75.2	------	95	1	86	50	12	64	33	66	62	71	5.27	+1.8	8	3,920	se.	24	sw.	1	17	8	6	3.6	0.0	0.0
Springfield, Mo	1,324	98	104	28.66	30.05	+.08	73.0	−2.7	91	1	81	55	13	65	24	66	63	75	10.68	+6.6	11	5,121	s.	30	nw.	9	16	10	5	3.5	0.0	0.0
Iola	984	11	50	28.99	30.01	+.05	76.6	−0.5	101	8	88	50	12	65	34	----	----	----	3.98	+0.5	9	3,095	s.	19	n.	9	11	13	7	5.2	0.0	0.0
Topeka	987	92	107	------	------	------	74.8	−1.4	96	1	85	54	12	65	36	----	----	----	6.48	+2.4	10	4,757	se.	35	nw.	31	11	13	7	4.9	0.0	0.0
Lincoln	1,189	11	81	28.76	29.99	+.04	75.1	+0.7	93	31	87	51	29	64	38	65	60	66	3.79	+0.2	9	5,296	s.	29	s.	1	10	13	8	5.0	0.0	0.0
Omaha	1,105	115	122	28.86	30.01	+.05	75.4	+1.0	92	23	86	53	11	65	33	64	58	63	4.43	+1.4	9	3,931	s.	32	nw.	31	17	9	5	3.6	0.0	0.0
Valentine	2,598	47	54	27.34	30.01	+.07	72.8	+1.1	98	13	86	43	11	60	40	60	53	57	2.58	+0.4	7	5,955	n.	32	sw.	13	11	13	7	4.9	0.0	0.0
Sioux City	1,135	94	164	28.80	29.98	+.03	74.8	+2.8	95	3	86	52	29	64	35	63	57	60	3.90	+0.8	7	6,987	s.	34	nw.	28	14	7	10	4.9	0.0	0.0
Huron	1,306	59	74	28.62	29.99	+.04	72.8	+3.4	102	4	86	45	30	59	45	60	52	54	0.60	−1.9	4	6,506	s.	28	w.	27	17	7	7	4.0	0.0	0.0
Pierre	1,572	70	75	28.32	29.96	+.02	75.2	+2.4	104	4	88	46	11	63	46	61	52	51	0.44	−1.6	5	6,525	e.	36	nw.	27	9	14	8	4.9	0.0	0.0
Yankton	1,233	49	57	28.70	29.99	+.04	75.4	+3.4	99	3	88	48	11	63	42	----	----	----	0.44	−2.6	6	4,504	s.	25	e.	18	13	10	8	4.6	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, August, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							68.9	+2.6										50	0.62	−0.6										4.0		
Billings	3,140	5	----	------	------	------	70.2	------	101	11	90	40	28	51	57	----	----	----	0.59	------	5	------	nw.	----	------	----	14	12	5	----	0.0	0.0
Havre	2,505	11	44	27.38	29.98	+.07	68.7	+3.3	96	20	84	45	9	54	46	54	44	50	0.22	−1.0	2	4,711	nw.	22	nw.	26	17	11	3	3.4	0.0	0.0
Helena	4,124	89	113	25.86	29.96	+.02	69.7	+4.7	95	11	84	44	28	55	43	55	45	47	0.06	−0.7	3	5,258	sw.	37	sw.	21	12	13	6	4.5	0.0	0.0
Kalispell	2,973	48	56	26.95	29.95	+.02	67.0	+4.2	93	17	84	40	8	50	42	51	36	40	0.01	−0.9	1	3,960	nw.	23	w.	26	14	12	5	3.7	0.0	0.0
Miles City	2,371	48	55	27.49	29.99	+.06	73.5	+2.0	98	19	87	47	28	60	38	58	48	48	0.17	−0.9	3	4,178	s.	31	nw.	26	19	7	5	3.3	0.0	0.0
Rapid City	3,259	50	58	26.67	30.01	+.08	71.1	+1.6	101	12	84	45	10	58	43	57	47	49	1.00	−0.7	11	4,842	n.	32	nw.	24	13	14	4	4.1	0.0	0.0
Cheyenne	6,088	84	101	24.16	30.00	+.08	66.6	+1.0	90	13	80	42	28	54	38	52	44	54	2.70	+1.2	11	5,443	w.	44	w.	26	10	14	7	4.8	0.0	0.0
Lander	5,372	60	68	24.77	30.00	+.08	67.8	+2.3	92	11	83	40	28	52	43	53	44	50	0.59	+0.1	5	2,931	sw.	35	nw.	23	16	12	3	3.5	0.0	0.0
Sheridan	3,790	10	47	26.16	30.00	------	69.2	------	97	11	86	39	29	52	50	55	47	56	0.14	−0.8	4	2,295	nw.	24	nw.	26	11	18	2	4.2	0.0	0.0
Yellowstone Park	6,241	11	48	24.03	30.03	+.10	62.6	+1.7	87	11	78	33	28	47	45	48	36	46	0.75	−0.3	7	4,336	sw.	30	sw.	7	10	16	5	4.7	0.0	0.0
North Platte	2,821	11	51	27.12	29.99	+.05	73.8	+3.0	98	14	87	44	29	60	47	61	54	59	0.58	−1.8	9	4,260	se.	21	ne.	31	16	7	8	4.1	0.0	0.0
Middle Slope							75.9	−0.1										57	2.33	−0.2										4.1		
Denver	5,292	106	113	24.85	30.00	+.08	72.2	+1.5	95	12	84	50	28	60	34	56	46	48	2.36	+0.9	7	4,262	s.	23	w.	26	14	11	6	4.0	0.0	0.0
Pueblo	4,685	80	86	25.39	29.97	+.06	74.0	+1.3	98	14	89	51	24	60	38	57	47	47	0.83	−1.0	8	3,875	e.	26	nw.	22	17	12	2	3.9	0.0	0.0
Concordia	1,392	50	58	28.58	30.02	+.07	75.4	−1.1	100	30	86	53	29	64	38	65	61	69	5.18	+2.3	12	3,920	s.	20	sw.	30	16	10	5	3.8	0.0	0.0
Dodge City	2,509	88	100	27.46	30.01	+.08	76.2	−1.5	104	26	88	56	11	64	39	63	57	59	1.52	−1.2	9	7,540	s.	32	e.	5	21	6	4	3.0	0.0	0.0
Wichita	1,358	139	158	28.59	29.99	+.04	77.2	−1.1	99	8	87	56	11	67	29	65	59	60	1.91	−1.2	9	7,014	s.	37	s.	31	12	12	7	4.7	0.0	0.0
Oklahoma City	1,214	10	47	28.74	29.99	+.05	80.2	+0.5	100	26	92	57	29	69	33	67	61	61	2.17	−0.7	7	5,452	s.	24	se.	31	10	13	8	5.1	0.0	0.0
Southern Slope							79.0	−0.6										60	1.94	−0.4										4.2		
Abilene	1,738	10	52	28.22	29.98	+.06	82.4	+0.4	99	6	94	60	11	71	32	66	58	53	0.31	−1.9	3	6,318	s.	30	sw.	31	11	13	7	4.5	0.0	0.0
Amarillo	3,676	10	49	26.35	30.00	+.08	76.1	+0.4	97	26	88	57	29	65	32	63	56	58	2.19	−0.9	8	5,200	s.	19	s.	30	13	12	6	4.5	0.0	0.0
Del Rio	944	64	71	28.97	29.94	+.04	82.0	−2.2	98	21	92	66	12	71	27	71	66	66	2.56	+0.8	4	5,894	se.	35	e.	22	13	17	1	4.0	0.0	0.0
Roswell	3,566	75	85	26.43	29.97	+.09	75.5	−1.1	98	27	88	55	11	63	38	63	57	61	2.71	+0.6	11	4,113	s.	27	ne.	20	15	11	5	4.0	0.0	0.0
Southern Plateau							78.2	+0.8										56	1.94	+0.8										3.8		
El Paso	3,778	152	175	26.22	29.91	+.07	79.5	+0.3	100	27	91	60	23	68	34	63	55	49	2.14	+0.4	8	5,634	e.	41	ne.	23	13	15	3	3.9	0.0	0.0
Albuquerque	4,972	51	66	25.14	29.90	------	74.4	------	95	26	88	54	13	61	37	59	51	52	0.23	------	6	3,696	sw.	24	se.	16	12	16	3	4.2	0.0	0.0
Santa Fe	7,013	38	53	23.41	29.95	+.06	67.0	−0.4	87	26	79	48	24	55	33	53	46	58	2.10	−0.2	13	3,156	e.	22	s.	29	13	12	6	4.5	0.0	0.0
Flagstaff	6,907	10	59	23.50	29.94	+.10	64.2	+1.4	86	24	78	46	24	50	40	54	----	72	3.56	------	15	4,042	nw.	26	se.	25	3	18	10	----	0.0	0.0
Phoenix	1,108	10	107	28.72	29.83	+.04	89.3	+0.8	110	19	101	72	31	78	33	71	62	48	1.70	+0.8	7	3,338	e.	42	s.	27	16	10	5	3.5	0.0	0.0
Yuma	141	9	54	29.68	29.82	+.06	90.1	−0.3	113	19	103	68	31	78	33	74	67	54	2.22	+1.7	8	2,941	s.	28	w.	31	19	8	4	2.0	0.0	0.0
Independence	3,957	6	27	26.00	29.94	+.13	79.1	+3.0	102	25	93	59	31	65	35	59	----	----	1.51	+1.4	5	------	s.	----	------	----	17	7	7	----	0.0	0.0
Middle Plateau							74.6	+3.5										36	0.61	−0.1										3.0		
Reno	4,532	74	81	25.51	29.90	+.06	74.2	+7.2	98	23	91	50	27	58	45	53	37	32	0.95	+0.7	1	4,135	w.	27	sw.	25	20	7	4	3.0	0.0	0.0
Tonopah	6,090	12	20	------	------	------	73.9	------	91	3	84	54	30	64	26	55	42	38	1.74	------	5	------	se.	----	------	----	----	----	----	----	------	----
Winnemucca	4,344	18	56	25.65	29.95	+.07	73.2	+3.9	99	3	92	44	22	54	54	51	32	27	0.16	0.0	2	4,433	sw.	26	se.	16	22	7	2	2.3	0.0	0.0
Modena	5,473	10	43	24.70	29.91	+.05	71.8	+2.6	97	25	87	48	28	56	41	55	44	46	0.46	−0.8	8	6,235	sw.	45	sw.	29	16	11	4	4.1	0.0	0.0
Salt Lake City	4,360	163	203	25.67	29.94	+.03	76.6	+2.1	98	23	89	55	27	65	33	57	43	34	1.07	+0.2	5	4,595	s.	42	w.	21	21	8	2	2.7	0.0	0.0
Grand Junction	4,602	60	68	25.43	29.94	+.04	77.2	+1.8	98	25	91	54	28	63	35	56	42	30	0.40	−0.8	3	3,629	se.	31	sw.	6	17	12	2	3.1	0.0	0.0
Northern Plateau							73.1	+3.2										34	0.09	−0.4										2.4		
Baker	3,471	48	53	26.48	30.00	+.05	68.6	+4.0	97	10	87	42	6	50	46	50	33	32	0.04	−0.4	3	3,529	se.	17	sw.	10	22	8	1	2.1	0.0	0.0
Boise	2,739	79	87	27.15	29.94	+.01	75.1	+3.3	100	10	91	49	27	59	41	55	38	30	0.05	−0.1	2	2,713	nw.	17	se.	14	21	7	3	2.6	0.0	0.0
Lewiston	757	40	48	29.16	29.96	+.01	75.0	+2.2	102	23	92	51	22	58	48	----	----	----	0.02	−0.6	1	2,276	w.	22	nw.	3	20	8	3	2.5	0.0	0.0
Pocatello	4,477	60	68	25.54	29.96	+.04	72.4	+2.8	97	11	86	45	27	58	44	54	39	38	0.54	−0.2	3	4,572	se.	41	sw.	18	13	10	8	4.5	0.0	0.0
Pasco	416	5	33	------	------	------	74.6	------	104	2	93	47	14	56	53	----	----	36	T.	------	0	4,981	sw.	----	------	----	26	4	1	----	0.0	0.0
Spokane	1,929	101	110	27.96	29.96	+.01	71.2	+3.1	97	17	87	47	8	56	44	52	35	33	0.01	−0.6	1	3,222	s.	19	s.	21	23	5	3	2.3	0.0	0.0
Walla Walla	991	57	65	28.90	29.96	.00	75.4	+2.7	99	1	89	54	8	62	41	56	38	30	T.	−0.5	0	2,726	w.	15	w.	5	26	4	1	1.5	0.0	0.0
Yakima	1,076	58	67	28.84	29.98	------	73.8	+4.3	99	2	89	50	6	59	39	56	41	36	T.	−0.2	0	4,363	nw.	21	sw.	3	29	2	0	1.2	0.0	0.0
North Pacific Coast Region							62.8	+0.6										68	0.18	−0.6										3.6		
North Head	211	11	56	29.90	30.12	+.09	56.7	−1.0	77	28	61	47	8	52	21	55	54	91	0.22	−0.8	4	9,066	n.	34	n.	1	4	17	10	6.1	0.0	0.0
Port Angeles	29	8	53	------	30.11	------	58.8	------	85	9	67	45	4	50	33	----	----	----	0.05	−0.7	1	3,921	sw.	29	w.	29	15	11	5	----	0.0	0.0
Seattle	125	215	250	29.94	30.07	+.07	64.2	+1.1	91	9	74	51	4	55	33	57	51	67	0.11	−0.6	4	4,203	ne.	21	s.	9	17	11	3	3.5	0.0	0.0
Tacoma	194	172	201	29.88	30.08	+.04	63.9	+1.3	94	9	74	49	16	54	38	----	----	----	0.21	−0.5	3	4,827	n.	45	sw.	9	13	16	2	3.8	0.0	6.0
Tatoosh Island	86	9	53	30.01	30.10	+.10	54.9	−0.4	67	9	59	47	20	51	15	54	53	94	0.83	−1.2	7	6,832	s.	40	s.	9	4	11	16	6.7	0.0	0.0
Medford	1,329	29	58	28.57	29.95	------	72.1	------	103	1	92	44	6	52	50	55	40	40	T.	−0.2	0	3,933	nw.	24	nw.	17	27	2	2	1.2	0.0	0.0
Portland, Oreg.	153	68	106	29.89	30.05	+.04	69.2	+2.5	96	28	81	52	4	57	35	59	52	60	0.04	−0.6	1	3,844	nw.	16	nw.	27	20	9	2	3.0	0.0	0.0
Roseburg	510	75	99	29.49	30.03	+.03	68.0	0.0	98	28	84	46	6	52	44	56	46	55	T.	−0.3	0	2,859	n.	18	n.	20	25	6	0	1.2	0.0	0.0
Middle Pacific Coast Region							68.1	+1.3										53	T.	0.0										3.1		
Eureka	62	73	89	29.99	30.06	+.06	55.3	−0.7	64	20	59	48	5	51	14	53	51	87	0.01	−0.2	1	3,468	nw.	17	nw.	11	6	15	10	5.7	0.0	0.0
Red Bluff	330	5	58	29.52	29.86	.00	82.4	+2.7	107	24	99	60	9	65	42	60	40	27	T.	0.0	0	3,219	s.	16	n.	26	26	3	2	1.5	0.0	0.0
Redding	722	20	34	------	------	------	83.6	------	106	24	98	62	7	69	34	----	----	22	0.00	------	0	4,876	nw.	----	------	----	23	8	0	----	0.0	0.0
Sacramento	69	106	117	29.80	29.87	+.02	74.6	+1.7	108	24	93	50	9	57	44	59	49	50	T.	0.0	0	5,449	s.	17	sw.	13	27	4	0	1.1	0.0	0.0
San Francisco	155	208	243	29.78	29.95	+.03	60.4	+1.3	89	23	68	51	9	53	35	54	51	79	0.00	0.0	0	4,964	sw.	22	w.	17	12	16	3	4.5	0.0	0.0
San Jose	141	12	110	29.80	29.95		68.0	+1.3	99	24	82	47	19	54	45	----		----	T.	0.0	0	3,621	nw.	20	se.	6	21	8	2	2.9	0.0	0.0
South Pacific Coast Region							78.1	+4.6										60	0.03	0.0										3.3		
Fresno	327	89	98	29.52	29.86	+.04	84.4	+3.7	110	24	100	63	19	69	39	61	42	27	T.	0.0	0	4,778	nw.	28	nw.	4	23	5	3	2.2	0.0	0.0
Los Angeles	338	159	191	29.57	29.92	+.04	76.1	+5.0	97	25	85	64	6	67	25	66	63	71	0.02	0.0	2	2,892	sw.	14	w.	24	20	8	3	3.1	0.0	0.0
San Diego	87	62	70	29.83	29.92	+.03	73.8	+5.1	88	28	78	65	21	69	16	68	66	82	0.08	0.0	4	3,961	w.	16	w.	19	16	9	6	4.5	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.92	30.01		81.4	+0.9	91	3	86	74	14	77	15	----	----	----	5.54	−0.4	23	9,162	e.	32	e.	8	8	17	6	5.3	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	------	[1] 29.82	−.01	81.2	0.0	92	21	87	72	8	75	17	----	----	[1] 86	4.28	−3.6	16	4,393	nw.	20	nw.	10	0	11	20	7.9	0.0	0.0
Cristobal	36	6	97	------	[1] 29.83	−.01	81.8	+1.6	90	22	87	74	6	77	16	77	76	[1] 85	17.52	+2.1	25	5,090	w.	26	w.	6	0	1	30	9.4	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2] 29.41	[2] 29.92	------	53.0	------	70	16	64	28	20	42	37	49	45	76	2.80	------	12	2,632	sw.	17	nw.	18	8	6	17	6.6	0.0	0.0
Juneau	80	11	50	[2] 29.96	[2] 30.05	------	55.6	------	74	10	60	46	4	51	25	53	51	88	11.31	------	23	3,541	s.	26	s.	10	3	1	27	8.7	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.97	[2] 30.01	------	78.6	+0.2	84	14	83	72	12	74	11	72	69	74	1.83	+0.6	14	6,767	e.	24	ne.	6	9	15	7	5.5	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, August, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				57.8		65.0	50.6	74	42	2.75		0.0
Sydney, C. B. I	48												
Yarmouth, N. S	65												
Charlottetown, P. E. I	38												
Chatham, N. B	28												
Father Point, Que	20												
Quebec, Que	296	29.70	30.02	+0.09	64.4	+1.3	72.9	55.8	84	46	2.31	−1.52	0.0
Doucet, Que	1,236												
Montreal, Que	187	29.79	29.99	+.04	69.0	+2.6	77.4	60.7	90	53	1.75	−1.82	0.0
Ottawa, Ont	236	29.75	30.01	+.05	70.2	+5.4	82.5	57.9	99	50	0.57	−2.46	0.0
Kingston, Ont	285												
Toronto, Ont	379	29.62	30.01	+.02	69.4	+3.4	78.3	60.5	92	46	2.10	−0.66	0.0
Cochrane, Ont	930				61.2		72.5	50.0	97	37	1.53		0.0
White River, Ont	1,244	28.69	29.99	+.03	58.0	+1.6	73.2	42.8	90	27	2.86	−0.44	0.0
London, Ont	808				69.0		80.2	57.9	96	40	2.60		0.0
Southampton, Ont	656												
Parry Sound, Ont	688	29.34	30.02	+.04	67.0	+3.5	76.5	57.5	88	46	1.71	−1.01	0.0
Port Arthur, Ont	644	29.30	30.01	+.05	63.7	+4.2	74.1	53.3	94	38	1.54	−1.21	0.0
Winnipeg, Man	760	29.13	29.94	.00	66.8	+3.4	78.2	55.5	100	36	2.02	−0.65	0.0
Minnedosa, Man	1,690	28.18	29.96	+.02	63.4	+4.0	76.5	50.2	98	36	2.96	+0.86	0.0
Le Pas, Man	860				62.2		72.7	51.7	83	39	2.88		0.0
Qu'Appelle, Sask	2,115	27.73	29.94	+.01	63.7	+2.2	76.2	51.2	92	35	2.45	+0.81	0.0
Moose Jaw, Sask	1,759				65.7		79.1	52.3	93	38	3.11		0.0
Swift Current, Sask	2,392	27.44	29.91	−.02	65.2	+1.2	79.6	50.7	98	36	2.16	+0.25	0.0
Medicine Hat, Alb	2,365												
Calgary, Alb	3,428												
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.42	29.97	+.05	63.5	+4.6	75.2	51.8	92	40	1.35	−0 80	0.0
Battleford, Sask	1,592	28.23	29.95	+.04	63.1	+0.5	76.8	49.4	99	38	0.82	−1.54	0.0
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.82	30.07	+.06	60.0	+1.3	68.0	52.1	84	50	0.20	−0.40	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

LATE REPORTS, JULY, 1931

Stations	Altitude	Station pressure	Sea level pressure	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Cape Race, N. F	99				55.8		60.0	51.6	74	45	2.44		0.0
Sydney, C. B. I	48	29.90	29.95	+.02	68.2	+5.9	77.3	59.2	87	50	2.10	−1.55	0.0
Halifax, N. S	88	29.84	29.94	−.02	67.0	+3.6	75.1	59.0	85	50	2.81	−1.24	0.0
Yarmouth, N. S	65	29.82	29.89	−.06	64.3	+4.8	71.7	56.9	79	46	1.31	−2.16	0.0
Charlottetown, P. E. I	38	29.80	29.84	−.06	69.0	+4.9	76.4	61.6	87	52	2.04	−1.45	0.0
Chatham, N. B	28	29.76	29.79	−.09	69.2	+4.2	78.7	59.8	91	48	4.18	−0.01	0.0
Father Point, Que	20	29.78	29.80	−.05	59.2	+1.6	67.8	50.6	82	45	4.68	+1.64	0.0
Quebec, Que	296	29.55	29.86	−.05	68.6	+3.1	76.9	60.3	86	51	3.70	−0.56	0.0
Doucet, Que	1,236				63.8		76.7	51.0	95	33	7.17		0.0
Montreal, Que	187	29.64	29.84	−.09	73.7	+5.2	82.8	64.6	97	56	4.23	−0.06	0.0
Kingston, Ont	285	29.58	29.88	−.09	71.6	+3.4	78.2	65.0	89	56	3.63	+0.74	0.0
Toronto, Ont	379	29.50	29.89	−.08	73.6	+5.6	82.7	64.5	98	54	3.10	+0.18	0.0
Cochrane, Ont	930				67.0		78.0	56.0	90	47	3.61		0.0
White River, Ont	1,244	28.55	29.84	−.10	63.6	+4.1	77.6	49.7	99	33	3.43	+0.63	0.0
London, Ont	808				73.2		84.3	62.2	99	50	5.64		0.0
Southampton, Ont	656	29.20	29.91	−.06	70.0	+5.3	79.0	61.0	92	50	2.69	+0.71	0.0
Parry Sound, Ont	688	29.22	29.90	−.06	70.8	+4.8	79.6	62.0	93	52	3.39	+0.77	0.0
Port Arthur, Ont	644	29.17	29.86	−.08	66.5	+4.5	77.5	55.5	94	46	2.63	−0.85	0.0
Winnipeg, Man	760	29.04	29.85	−.08	68.4	+2.4	79.4	57.4	98	48	3.08	0.00	0.0
Minnedosa, Man	1,690	28.09	29.87	−.06	65.0	+2.8	76.9	53.2	98	43	2.99	+0.39	0.0
Le Pas, Man	860				64.1		74.6	53.5	91	42	2.84		0.0
Qu'Appelle, Sask	2,115	27.65	29.86	−.06	65.8	+2.3	78.6	53.0	101	40	1.80	−0.68	0.0
Moose Jaw, Sask	1,759				69.3		83.3	55.2	102	44	0.73		0.0
Swift Current, Sask	2,392	27.38	29.84	−.07	67.6	+1.1	82.6	52.7	103	40	1.18	−1.26	0.0
Prince Albert, Sask	1,450	28.34	29.89	−.02	65.7	+3.8	77.2	54.3	93	45	1.25	−0.80	0.0
Battleford, Sask	1,592	28.16	29.87	−.03	65.0	+0.3	78.0	52.0	91	39	1.20	−1.14	0.0
Edmonton, Alb	2,150	27.63	29.87	−.03	61.5	+0.9	73.5	49.6	88	39	3.06	+0.03	0.0
Victoria, B. C	230	29.76	30.01	−.04	61.5	+1.5	69.7	53.3	86	49	0.33	−0.07	0.0

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A SUMMER CRUISE IN THE WEST INDIES

By R. DeC. Ward

[Harvard University, Cambridge, Mass., August 14, 1931]

INTRODUCTION

Need of rest, and a renewed interest in the West Indian region because of the preparation (in collaboration with Prof. Charles F. Brooks) of the chapter on the climatology of the West Indies for the new Köppen-Geiger *Handbuch der Klimatologie*, were the reasons for taking a month's cruise to the Lesser Antilles during the summer of 1931.

The instrumental equipment was purposely reduced to a minimum—a pair of traveling pocket dry and wet bulb thermometers and a small-size Richard barograph. This latter instrument went with the writer around South America in 1897–98, on the International Ice Patrol in 1923, and around the world by sea in 1929. In addition, copies of the latest United States Hydrographic Office Pilot Charts of the North Atlantic and of the Central American waters were also taken. No attempt was made to take regular observations at fixed hours. The thermometers were read and record of wind, cloudiness, etc., was made, when and as such observations were convenient and seemed desirable.

As it was my desire to visit some of the smaller and less well-known islands, one of the Canadian national steamships of the "Lady" class, assigned to the so-called eastern route, was chosen as best and most conveniently fulfilling the requirements. The regular schedule includes calls at Bermuda, St. Kitts, Nevis, Antigua, Montserrat, Dominica, St. Lucia, Barbados, St. Vincent, Grenada, and Trinidad, with the terminal port at Georgetown (Demarara), British Guiana. The same ports, in the reverse order, are touched on the return voyage. The round trip takes one month.

GENERAL GEOGRAPHY

The islands comprising the West Indian archipelago form a natural breakwater on the eastern border of the Caribbean Sea and the Gulf of Mexico, reaching from latitude 10° No. (Trinidad) to somewhat beyond the Tropic of Cancer (Bahamas). As a whole, these islands form a more or less regular arc or parabola, stretching from Yucatan and Florida to the coast of Venezuela. The Greater Antilles—Cuba, Haiti, and Santo Domingo, Jamaica, and Porto Rico—extend eastward from off Yucatan. The Lesser Antilles extend from east of Porto Rico to the Orinoco Delta in a sweeping curve slightly convex to the east. Trinidad, the southernmost of this group, is really a detached portion of the South American Continent.

The West Indies include an immense number of islands and islets, ranging in size from the larger ones with mountains of considerable elevation and elevated plateaus to the smallest rocks and keys which hardly rise above the surface of the sea. The islands differ from one another, not only in size but also in detailed physical characteristics and in population. The highest mountains are in the northern islands, while the volcanoes, whether active or dormant, are in the Lesser Antilles. With the exception of the Bahamas, the large majority of the islands are mountainous. Several are distinctly rugged. The western or interior zone of the Lesser Antilles is volcanic. The outer zone from the Bahamas to Barbadoes, is limestone. In Guadeloupe, which is volcanic in the west and limestone in the east, the two formations converge. The soils of the volcanic islands are wonderfully fertile and support luxuriant vegetation. The limestone islands, whose soils are generally less fertile, are regarded as "healthier" and are obviously subject to fewer dangers.

The use of the names Windward and Leeward for two divisions of the Lesser Antilles group is of interest to the climatologist. These terms are naturally associated with the steadiness of the trade winds, just as many other geographical designations had their origin in meteorological or climatic characteristics. The application of the term Leeward to the northern members of the Lesser Antilles, and Windward to the southern islands would seem to be illogical and inappropriate. The more northerly islands are certainly farther to windward if the normal direction of the northeast trade is considered to be the controlling factor. On the other hand, as the prevailing direction of the trades is more or less easterly throughout much of the year over most of the islands, it would perhaps seem more logical to call the easternmost islands Windward and those to the west Leeward. As a matter of fact, the name Windward recalls the track followed to the Spanish Main in the old sailing ship days, and the real Leeward Islands are those off the north coast of South America. In the new Oxford Advanced Atlas (Bartholomew), while the names Leeward and Windward are shown for the northern and southern islands of the Lesser Antilles, respectively, the islands off the Venezuelan coast are designated "Leeward Islands (of the Spanish)." Officially, the British Leeward Islands include those between the Virgins and Dominica, and the Windward Islands extend from St. Lucia to the south.

HISTORY

Historically the West Indies region is full of interest, of romance, and of thrilling tales of the old pirate and buccaneer days. Columbus, on his first and most

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famous voyage, reached the Bahamas (1492), and on his later voyages discovered most of the larger islands. The name West Indies perpetuates the original conviction of Columbus that he had discovered a western route to India, and the name Antilles recalls the fact that he was thought to have reached the fabled land of Antillia. Spain naturally claimed the whole archipelago, but she was not allowed to remain in undisputed possession. British and Dutch sailors were before long cruising in the West Indian waters. Spain began to lose ground, and toward the end of the seventeenth century relinquished her claim to exclusive possession. As the power of Spain declined, other nations gained foothold, notably the English, French, and Dutch, and later the United States. Political changes have been frequent, and are rather hopelessly confusing, many of the islands having changed hands more than once. Porto Rico became a United States possession after the war with Spain, and St. Thomas was later purchased by the United States from Denmark. These changes are, however, of comparatively little concern to the casual traveler, who is mainly interested in sailing over the tropical seas, in enjoying the charms of the tropical vegetation, and in visiting new scenes.

The earliest conquerors expected to find great wealth of precious metals in the islands, but in this hope they were disappointed. The abundance of gold and silver came from the mainland to the west, and the dispatch of treasure-laden ships to Spain naturally served as an irresistible attraction to pirates and buccaneers. Many names of the early navigators became famous in history, e. g., Sir Francis Drake and Sir John Hawkins, who came to the West Indies as privateers and died there. Other names also associated with these islands are Sir Walter Raleigh, Lord Nelson, Rodney Hood, Benbow, and others. Raleigh made his famous expedition to the Orinoco from the island of Trinidad. The Spanish Main was long infested by pirates and marauders—British, Dutch, and French. Legitimate trade suffered. Ordinary commerce could only be carried on under conditions of extreme danger and difficulty and by force of arms. Piracy finally became a decreasing menace in the earlier years of the eighteenth century, but it persisted, more or less sporadically, along the coasts as late as the early part of the nineteenth century.

The wealth of the West Indies has been in their agricultural resources, not in the output of precious metals. The extended and systematic cultivation of sugar-cane, from about the middle of the seventeenth century, marked the beginning of the prosperity of the islands, and was made possible by the introduction of African negro slave labor. From an economic point of view, slave labor was a success. In the slave traffic all the nations having possessions in the West Indies took part. The cessation of the traffic in slaves; the emancipation of the slaves; competition with European beet sugar whose production dated from the Napoleonic wars and was encouraged by bounties, and other political and economic factors, combined to bring about a gradual decline of West Indian prosperity in the nineteenth century. Labor became scarcer, more expensive, and less reliable. Fortunes were lost, and a long period of depression set in. More recently, with the introduction of other staple crops, diversified agriculture, and improved methods of cultivation, the general conditions have somewhat improved. Nevertheless, as is well known, tariff laws and regulations of other countries, and numerous political changes and upheavals of more recent days, have been serious handicaps in the development of sound and stable prosperity in these islands.

POPULATION

Chiefly because of the introduction of negro and other labor, the population of the West Indies has become very mixed. The great bulk of the people are still of pure African blood. European-negro mixture comes next; and there are also coolies from India, Chinese, and a very few aboriginal Carib Indians. The whites play the most important part in the administrative and commercial life of the archipelago, but are very distinctly in the minority.

CLIMATE

The larger climatic characteristics of the West Indian region are easily summarized. They are very simple and very uniform.[1] The climate is typically tropical, with great uniformity of temperature, and with normal modifications resulting from latitudinal, topographic, and insular controls. With the exception of the Greater Antilles, the islands are small and therefore the land effects are generally subordinate to those of the water. Near sea level over most of the area, the mean annual temperatures are between 77° and slightly over 80°; the means for the coolest month are mostly between a little over 70° and somewhat under 80°; those for the warmest month between 80° and a few degrees above 80°. The Lesser Antilles have mean annual (sea level) temperatures of 79° or thereabouts, running about 2° higher than those of the larger and more northerly and westerly islands of the Greater Antilles. The mean annual ranges are of the order of 3° to 5° in the southern islands and 10° or slightly more in the Bahamas and Cuba. In the Greater Antilles minima near sea level have mostly ranged between 50° and 60°; in the remaining islands, between 60° and 65° or slightly higher. The absolute maxima have run, in round numbers, between 90° and about 100°. In the mountainous islands relief from the heat of the lowlands may be found on the slopes and uplands, varying elevations providing a corresponding variety of climates.

The North Atlantic high-pressure belt lies to the north and northeast of the West Indies throughout the year. It has its greatest extent in summer, at which season there is a slight increase in pressures over the islands. The area lies well within the northeast trades and winds from northeast or east prevail, there being no noteworthy changes in direction. At many stations, and especially in the easternmost islands, the mean direction is fairly steadily easterly. With the advance of summer, east and southeast directions become more frequent, and the velocities are somewhat lower. Under favorable conditions of exposure and of topography, land and sea breezes are well developed in many places. On the windward sides of the islands the sea breeze increases the velocity of the on-shore trades during the daytime. Winds from the sea, whether normal trade or sea breeze or the two combined, help greatly to temper the heat on land. Gales rarely occur, the southern islands being especially free from them. Extreme velocities of 100 or more miles an hour have occurred during hurricanes.

Differences of rainfall rather than differences of temperature distinguish the seasons, this being a general characteristic of tropical climates. The rainfall is heavy, or at least abundant, nearly everywhere. The windward mountain slopes naturally have the largest amounts; the leeward slopes and the interiors are much drier. Under varying topographic controls, great contrasts

[1] For a detailed account, with numerous tables and a complete bibliography, see the sections on the West Indies, by R. DeC. Ward and Charles F. Brooks, in the new Köppen-Geiger *Handbuch der Klimatologie*. The numerical data given in the present paper are generalized.

are found within very short distances. In the Leeward Islands the mean annual rainfall is generally more than 45 inches; on most of the islands it is 80 inches or over; at the highest elevations it is more than 150 inches. In the Windward Islands it varies between a little over 40 inches to about 120 inches, several stations showing annual means well over the latter amount. The months of maximum and of minimum rainfall vary somewhat in different parts of the West Indies, as well as on the individual islands. The rainiest months are usually from June to November; the driest, from January to April. The pressures are then relatively high, and there is the greatest frequency of northerly winds. The rainy season is, in general, a double one, with maxima in May (June or July) and in October or November, corresponding to two periods of lower pressure. This is also the time of most active convection and of many thunderstorms. October, usually wetter than May, is the time of lowest pressure and of hurricane rains. As the trades are forced to ascend the mountains throughout the year, the windward slopes have rainfall in winter as well as in summer, especially at the greater elevations. The lee slopes and the interior portions of the mountainous islands have relatively dry winters. These receive the bulk of their rainfall in the warmer months, when convection is most active. The southern islands generally have their first maximum retarded to June, July, or even August, and the second to November. The general régime is therefore a drier season in late winter and spring, and a rainier season in summer and autumn.

Relative humidity averages between 70 per cent and 80 per cent, or even more. It is generally at its minimum in March or April, at the season of least rainfall, and at a maximum in the autumn, when the most rain falls. The air is naturally damper on the windward than on the leeward sides of the islands. Fog is practically unknown in the waters of the Spanish Main.

The only violent weather phenomenon is the hurricane. In late summer and autumn, toward the end of the rainy season, and much less often in early or midsummer, violent tropical cyclones occasionally visit portions of the West Indies group. They are most frequent in the northern islands. The most violent ones may cause a heavy loss of life, and do great damage to buildings and crops. In their season, they are a menace to navigation. The more southern islands are rarely visited by them.

The available date regarding thunderstorms are scattering and incomplete. From November to April there are very few such storms, and over the smaller islands they are practically unknown between January and April. May and June show a marked increase in frequency, with a maximum in July to September.

The winter will doubtless always be the popular season for northern tourists in the West Indies, yet climatically the "winter" and the "summer" are so much alike that there is but little to distinguish them from one another, at least in so far as the temperatures are concerned. This is especially true of the Lesser Antilles, and notably so of the southernmost islands. The "summers" are there practically the same as the "winters," although the absolute maximum temperatures run a little higher in the "high sun" season. The Greater Antilles, farther north and nearer the continent, have slightly more marked temperature differences between the seasons. During the winter months the minima are somewhat lower there than farther south, and occasional importations of greatly tempered "cool waves" from the continent reach these islands, as in the case of the "northers" of Cuba. On the mountain slopes of the well-known Greater Antilles the climate is naturally cooler and more invigorating, especially in winter, than in the case with the coasts of the southern islands of the Lesser Antilles. It is, however, a mistaken but very widespread popular notion that summer is a wholly impossible season for visiting the West Indies. The statement in a standard publication of recent date, that the heat increases in July "to an extent well-nigh unbearable" is misleading. The summer months are, it is true, generally more rainy than those of winter, and the occasional hurricanes of late summer and autumn are certainly somewhat repellent. Yet rain occurs more or less frequently in all months, and hurricanes are fortunately few, and usually far between. The desire to escape from cold, and snow, and ice, and rough weather will, however, always tempt northerners to crave the bright sunshine, blue seas, and balmy air of the Spanish Main in winter. The summer provides sufficient heat and pleasant outdoor conditions in the homeland. The great American trek in summer is northward to the mountains, seashore, and lakes, or eastward across the North Atlantic, not southward to the everlasting summer of the Tropics.

SUMMARY OF WEATHER CONDITIONS AT SEA JULY 9 TO AUGUST 6, 1931

The following notes were made from day to day during the cruise, and were written up at sea. No attempt has been made to consult reference books or to verify every statement.

I have often been asked what interest there can possibly be in traveling over seas and to lands whose weather conditions and climates are already well known, and have been described by previous writers. The answer is very simple. Between seeing a condition which is presented graphically on a chart or reading a description of it in print, and actually feeling and observing the same condition one's self, there is all the difference between the dead fact and the living reality; between a mere quotation and the vivid recollection of a personal experience. "Wandering in search of weather" is a fascinating pursuit, in which everyone who attempts to teach the science of the earth's atmosphere should engage whenever possible. Furthermore, weather types and climatic conditions, wherever met with, almost always present certain aspects which did not attract the attention of previous observers. Hence the thrill of possible discovery always stimulates the "weather hunter." On this particular voyage there was the added interest of visiting the places at which the longest and best series of meteorological records have been kept in the islands at which stops were made—records which, in connection with recent work on the climatology of the West Indies, proved of great value. Basseterre (St. Kitts), Charlestown (Nevis), St. Johns (Antigua), Plymouth (Montserrat), Roseau (Dominica), Castries (St. Lucia), Bridgetown (Barbados), Kingstown (St. Vincent), St. George (Grenada), Port of Spain (Trinidad), were all familiar names, as was Georgetown (British Guiana).

To give anything more than a very brief summary of the observations made on the trip would weary the reader and would serve no useful purpose, although taking these observations added greatly to the interest of the cruise.

A barograph is a most welcome companion on an ocean voyage, whether it be in the stormy belts of the prevailing westerlies or in the uniform pressure conditions of the trades or doldrums. That wonderful double

diurnal maximum and minimum, traced day after day with clocklike regularity in the Tropics, never ceases to have a fascination for me. My collection of barograph curves, traced during previous ocean voyages, contains many weeks' sheets showing this remarkably uniform diurnal variation. The story of the pressure record made by the barograph on the present trip is easily told. The highest point on the outward voyage was reached near Bermuda (30.2 inches, uncorrected). From the crest of the North Atlantic high there is a slow decrease toward the equatorial low-pressure belt to the south. This was clearly indicated on the barograph curve. A pressure of about 30 inches was reached near the central portion of the Lesser Antilles. From there to the north the readings were somewhat higher; to the south, somewhat lower. The diurnal variation, faintly perceptible about 2° to 3° south of Bermuda, was marked throughout the whole trip from about 28° N. to Demerara and back. The lowest readings were between 29.75 inches and 29.8 inches (uncorrected), in Demerara. Between Boston and Bermuda the winds on the outward voyage were southeast. Soon after leaving Bermuda, and throughout the whole voyage to British Guiana and back, the ship was in the northeast trades. The northern limit of these winds (about lat. 28° N. in July) was passed without any change in wind direction. In this western part of the North Atlantic in summer the trades blow prevailingly from points between east and south-southeast, as is consistent with the rotary anticyclonic outflow on the western side of the North Atlantic high. The winds south of the northern limits of the northeast trade were Northeast, East, or Southeast, mostly of force 3 or 4, occasionally with higher velocities during squalls. There were also a few days with very light breezes. The southern limits of the northeast trade in July (lat. 10° N.) are in the latitude of southern Trinidad, and the northern limits of the southeast trade are at about latitude 6° N., just off the coast of Dutch and French Guiana. The ship encountered no "equatorial calms" during her two crossings from trade belt to trade belt, nor was there any really normal doldrum weather. The winds remained light to fresh from easterly points, and the weather was fairly typical of the trades, with some squalls. It will be remembered that typical doldrum conditions are not, as a rule, characteristic of this part of the western North Atlantic, and that the chances of finding light winds and calms are considerably fewer here than in the equatorial low-pressure belt off the west coast of Africa.

Those who think that steaming in the trades is monotonous can have little appreciation of the ever-changing panorama of the clouds. There are those wonderfully bright days when the blue skies are dotted with typical trade cumuli, their tall columnar forms leaning over to leeward, their tops breaking off and drifting away, dissolving as they go, and being replaced by new tops. There are days when conditions favor more active cloud growth, when cumulo-nimbus is the characteristic cloud form, when the skies are darker, when there are brief showers accompanied by slight squall winds—almost typical doldrum conditions. There are also dull days, when the skies are gray, and one is reminded of overcast days at home; and there are days when the sky is clear from morning to night. Surely, the sea traveler with his eyes open should never complain of monotony in the trades. These variations in the types of clouds and in the amounts of cloudiness are puzzling, in view of the fact that the air temperatures, the relative humidities, and the wind direction and velocity observed on board ship do not vary appreciably on days of widely different cloud conditions. The explanation is doubtless to be found in varying conditions aloft. The writer has spent, in all, several weeks in the trades, in North and South Atlantic, North and South Pacific, and in the Indian Ocean, and he has never failed to find interest and variety in the ever-changing cloud forms. On this voyage he was again impressed by the growth of the trade cumulus and rudimentary cumulonimbus in the later afternoons and early evenings, often to the shower stage. These growing cloud tops, illuminated by the setting sun, are beautiful to watch. Increased convectional ascent as the sun goes down is doubtless due to radiation from the tops of the clouds themselves.

Temperature observations on board ship were made in the shade, in well-ventilated locations, by sling thermometer. They ranged, roughly, between 75° and 85° most of the time, rising very slowly toward the south, where the readings during the daytime and early evenings remained steadily about 83° to 85°. The relative humidity was high and the air on shore was distinctly of the "hot-house" type. Under such conditions, walking in the narrow streets, under the tropical sun, and out of the wind, was always extremely uncomfortable. On the other hand, relief could always be found on board the ship, even when she was at anchor, because of the light or fresh breeze which was practically always present. The maximum observed on board was 86.5°. The official maximum on land was 90.2° (Bermuda). The most uncomfortable conditions on board ship were felt when the anchorage was close inshore, in the lee of hills that cut off the refreshing trade winds. Forced ventilation was used during the whole trip, and in addition electric fans were in constant operation in staterooms.

There were no gales; there was no fog after leaving the Massachusetts coast; there were no hurricanes. Those who dread the storms, gales, fogs, rough seas, and changeable weather of the much-traveled northern North Atlantic will find the poetry and charm of the ocean in the uniformity of temperature, bright skies, smooth fogless seas, and gentle trade winds of the Tropics. The complete meterological ignorance of the average passenger was illustrated time and again by such remarks as "how lucky we are to have such a fine breeze"; or "it is fortunate that the sea is so smooth"; or "I hope we shall have no fog".

BERMUDA

The Bermudas are in reality a modified coral atoll, resting on a submarine mountain. These coral islands lie farther north than any others of similar origin, a fact due to their position in the warm waters of the Gulf Stream eddy.

> By the gay borders of Bermuda's isles
> Where spring with everlasting verdure smiles.

So runs the poet's climatic summary. The mild and equable climate, accessibility, extensive advertising, and other factors, have combined to make Bermuda an increasingly popular winter resort. The winter months are and will remain the most alluring season; the summer, so far as maximum temperatures are concerned, is not as hot as are our own hot waves, but the cool spells brought by our summer "cool waves" and by our cyclonic onshore easterly winds along the Atlantic coast are wholly lacking. The marine type of retarded maximum and minimum temperatures is clearly indicated. August is the warmest month (mean slightly over 80°) and February or March the coolest (a few degrees over 60°). In an average winter the thermometer does not fall below 40°,

and is oftener near 60° than 40°. In summer, the maxima are oftener below than above 90°. Frost and snow form no part of the picture.

The Bermudas lie throughout the year in the western portion of the North Atlantic anticyclone. The mean wind direction is southwest, somewhat more northerly in winter and more southerly in summer. The winter winds are tempered by the warm waters over which they blow. On the other hand, the prevailing wind of summer imports high temperatures which one writer has described as "oppressive heat" between July and October, especially in August, and as resembling a "vapor bath". People who have lived for years in the fresh trade winds of the West Indies report Bermuda as seeming much the warmer and more enervating, especially at night. Bermudians, however, maintain, and rightly so, that they have a more equable summer climate, with less high maxima, than is found over much of the United States.

Occasional hurricane winds, and not infrequent winter gales, are irregular visitors. The rainfall is moderate. Hamilton has slightly over 50 inches, with maxima in January and April. There is greater probability of rain in winter, when extra-tropical cyclonic storms reach the islands, and less in early summer. The main source of water is rain caught in cisterns. During the past winter, water was brought from the United States to supply the needs of the winter visitors. The relative humidity remains between 70 per cent and 80 per cent throughout the year.

The vegetation of Bermuda is less characteristically tropical than that of the Antilles. The rainfall is less and the winters are cooler. Many tropical fruits and economic plants are, however, successfully cultivated. Bermuda is famous in the United States for its early vegetables, especially potatoes, its onions, and its Easter lilies.

The local weather reports for the two days preceding the writer's first visit showed clear to fair skies, maximum temperatures of 84° and 85°; minima of 75° and 76°. The temperatures of late afternoon and evening on board were 77.5° and 76.5°, respectively. The local newspaper reported: "There has been a strong southerly wind all of the past week, so that yachting and boating of all kinds in the Great Harbour has been difficult and unpleasant." On the second stop, the skies were cloudless, the wind light northerly, and the temperatures on board (8 a. m. to 1 p. m.) between 82° and 84°. The official record for August 3 was as follows: Maximum, 90.2°; minimum 74.2°; rain, 0.00 inches; barometer, 30.15 inches (a. m.) to 30.13 inches (p. m.); mean wind velocity, 17 miles an hour; sunshine, 9 hours, 20 minutes.

THE LESSER ANTILLES

The volcanic islands of the British Lesser Antilles all have certain common characteristics, and present much the same general appearance. They owe their picturesqueness, as well as their fertility, to their volcanic origin. Their mountains are sometimes symmetrical volcanic cones; sometimes rugged peaks and sharp serrated ridges; sometimes only gently rolling hills. There is usually one dominating volcanic summit, like Mount Misery on St. Kitts, the Soufriére on Montserrat, the Morne Diablotin on Dominica, again a Soufrière on St. Vincent, rising to between 3,500 and somewhat over 5,000 feet above sea level. Dense forests cover the slopes and reach up to the tops of most of the mountains, while over the lower slopes and in the fertile valleys stretch the cultivated fields, with their pleasing variety of different shades of green, broken here and there by the dark rich soil of freshly-tilled patches awaiting the next crops and by picturesque coconut, mango, and banana groves. Very beautiful everywhere are the brilliant colors of the many tropical flowers, notably poinsettia, hibiscus, bougainvillea, royal poinciana, and lilies of various sorts. Only a small portion of any of the islands is cultivated.

Climatically, all the islands are essentially alike, as has been indicated in the introductory summary. All have wetter windward and drier leeward sides. All have cloud caps and cloud banners over their higher mountain tops. All show typical diurnal-cumulus cloud development, and, especially in the afternoon and evening, have local showers from their massive cumulo-nimbus clouds. All have essentially the same vegetation and agricultural products. In all of them the capital and chief port is on the leeward side, where the water is smooth. From a shipping point of view the advantage of such a location is obvious. The disadvantage is that the velocity and steadiness of the trades are considerably decreased, and the feeling of heat is greater.

In size the various islands visited range from 30 to 300 square miles in area. Some of them are so close together that two were visited on the same day, with a stop of several hours at each island. Taking the Lesser Antilles in sequence from north to south they average only about 30 miles apart.

The early prosperity of the West Indies was built on sugar, cultivated by slave labor. After the abolition of slavery, with a large negro population no longer compelled to do hard work, a distinct decline began. Further, the present depression in the sugar market, resulting from overproduction of cane and beet sugar, has had most unfortunate economic consequences in the West Indies. In fact, it is probably no exaggeration to say that the large majority, if not all, of the islands are in a state of stagnation, if not of still progressive decay. Sugar, molasses, and rum still lead the list of agricultural products in most of the islands visited. Coconuts, coconut oil and copra, cocoa, limes, bay rum, arrowroot, mangoes, bananas, bread fruit, sweet potatoes, Indian corn, spices, etc., are also characteristic products. The islands differ considerably in their individual products, and details concerning the special products of each island would be wearisome and of no value in the present article. The cargo picked up by the ship at the different ports and landed at other ports, showed clearly that the products are not all alike. It was noticeable that the Demarara rice was brought north to several of the islands, and that mangoes, limes, avocado pears, and coconuts were shipped to Barbados, Bermuda, and Canada. The efforts now being made throughout the islands to find new crops and other substitutes for sugarcane are almost pathetic. On one island the development of a livestock industry, in another the raising of vegetables for the Canadian winter market, in another the planting of cocoa, in another the cultivation of citrus fruits—these are more or less random illustrations of hopes which are held for future success. The government agricultural departments are doing their part in experimental work with various plants and crops, as may be seen on a small scale in the botanical gardens in Dominica, St. Lucia, and St. Vincent. The experiment-station work in Barbados and Trinidad and in Georgetown (British Guiana) has already accomplished important results, and is full of promise for the future. Small wonder is it that the British West Indies are very seriously agitating federation, accompanied by complete dominion status, and that every effort is being made to cultivate reciprocal trade relations with Canada. The regular service maintained by the Canadian National

Steamships is striking evidence of the increasing closeness of these relations with Canada. Every automobile seen in the islands was "made in Canada."

St. Kitts, the first of the Leeward Islands visited on the voyage south, is the oldest British settlement in the West Indies. From Basseterre, its chief town, there is a good series of meteorological records. Of St. Kitts one writer has said: "The bracing qualities of the atmosphere are portrayed in the general good health of the inhabitants. The mornings and evenings of the hottest days are agreeably cool." Yet another has said: "Basseterre is not the most healthful (place) in the islands, but from November to May or June it is safe to live in." Very beautiful were the cumulus clouds on Mount Misery, forming and dissolving in the fesh trade winds, and very easy was it to determine the prevailing wind direction by means of the rows of windblown coconut palms in exposed locations.

Nevis has a name of meteorological origin, wrongly applied. Columbus named it Nieve in 1493 because of the white clouds which he saw enveloping its highest mountain, a cloud cap the same in appearance to-day as it was when Columbus first saw it. Nevis, once the social center of the West Indies, the birthplace of Alexander Hamilton, and the island on which Lord Nelson was married, is to-day a mere economic ghost of its former self. There is a vivid recollection of a drive around Nevis on a brilliant afternoon; of the marked difference between the vegetation and general condition of the population on the leeward and windward sides; of abandoned sugar mills and shacks on formerly prosperous estates; of ancient stone windmills now falling to ruins; of the smoke from dry cotton plants burned after the harvest; of the fires of the charcoal burners on the mountain. That Nevis is within the hurricane belt was evidenced by the coconut palms lying prostrate as the result of the 1928 hurricane, and by the fact that the windmills still in use in harvest time had had their "sails" removed in anticipation of the coming hurricane season.

Antigua the seat of government of the British Leeward Islands colony, has less elevation than the other volcanic islands, and this fact is inevitably reflected in the relatively small rainfall. The maximum altitude in the Shackerley Mountains is 1,500 feet. A pleasing variety of rolling hills and cultivated valleys is the feature that strikes the tourist as his ship enters the open roadstead of St. Johns and anchors 2 or 3 miles offshore. The excursion to English Harbor is full of historical interest. Here Nelson and Rodney careened and refitted their ships. Here may be seen the old dockyards, barracks, shipbuilding sheds, cannon, anchors and anchor chains, ships' figureheads, and other naval relics of olden days. The drive to English Harbor also gives an excellent cross section of the agricultural activities of the people.

W. H. Alexander has written of Antigua:

> Owing to a light rainfall, the elevated portions of the island are not clothed with the luxuriant tropical vegetation to be seen in other of the Leeward Islands, such as St. Kitts, Montserrat, and Dominica, but presents to the eye a rather desolate, uninviting appearance. The valleys, however, stand in marked contrast to the hills, being arrayed in all the beauty and vernal richness of a tropical climate. There are no rivers, and but few springs, and these are brackish. The people are dependent upon rainfall for a water supply, and have in former times suffered great loss and inconvenience from droughts.

The lack of any considerable elevations which would force the trade winds to climb higher, and thus cause more condensation, is the obvious reason for the relative dryness. One of the picture post cards on sale in St. Johns shows government officials supervising the rationing of water in a native village during a drought. On the other hand, another writer says:

> Antigua is so generally spoken of as a dry-as-dust place, where the earth refuses to yield water for the use of man, that I received more than ordinary pleasure in gazing on the wooded hills and green vales which decorate the interior of the island. (H. Coleridge: "Six Months in the West Indies in 1925.")

The historical records of Antigua mention damage by hurricane winds at none too infrequent intervals.

On Montserrat the traveler, especially one in search of climatic responses, should take the motor drive from Plymouth across to the windward coast. In some respects there are similar contrasts to those seen on the famous Pali drive from Honolulu, but the latter is far more beautiful and impressive. Ascending by a good motor road from Plymouth, the terraced hillsides show intensive and effective cultivation. Cotton, grown even well up on the lower slopes, and Indian corn are here the chief crops. Breadfruit, sweetpotatoes, and cassava are also seen. At the highest point on the road, where there is a beautiful view over the ocean to the east, the trades are found blowing with added velocity, and the great dark rolls of cumulus and cumulo-nimbus clouds on the windward slopes and on the tops of the mountains are beautiful illustrations of the effects of the forced ascent of the trades. "Montserrat lime juice" was formerly the chief product of the island, and is still widely known, but of late years the lime-fruit industry has fallen off.

Wonderfully beautiful were the great masses of cumulo-nimbus clouds towering above the mountains of Dominica as the ship neared that island in the early morning, the tops of the clouds brilliantly illuminated by the rising sun, while below, in shadow, the dark gray and purplish colors stood out in marked contrast. The elevation of Dominica insures abundant rainfall. There are said to be 365 rivers on the island. Many old plantations formerly devoted to sugarcane are now being planted with limes, coco, and spices. The exports from Roseau on the day preceding the arrival of the *Lady Hawkins*, as reported by the customhouse, were cocoa, copra, ginger, bay oil, and fruit. Hurricane winds have been responsible for great damage to the trees, coconut palms in particular. C. W. Bellamy has written:

> The relaxing, enervating moisture of the air, the scorching, blazing heat of the sky, or the parching drought of the winds * * * are alike unknown in Dominica. * * * Hot days in the height of the summer season are only to be expected in these latitudes.

To the truth of the latter sentence the casual traveler who walks through the narrow streets of Roseau on a bright July day will certainly testify. In the local newspaper there were advertisements of hurricane insurance, and, "for the hurricane season," hurricane lanterns. A letter to the editor, referring to the government notices regarding hurricane precautions and hurricane relief measures, expressed regret that so much publicity was being given to this subject because of the unfortunate reaction in the minds of those who might be thinking of settling in the island.

St. Lucia is the largest and most northerly of the British Windward Islands. Castries, the chief town, lies on a deep and well-protected harbor, one of the finest in the West Indies. It was formerly a very important coaling station, but has lost its commanding position since the opening of the Panama Canal and the advent of oil-burning steamers. It is picturesque, but dead. Its few white inhabitants fly to the cooler hill slopes at night. From the wireless station, 800 feet above Castries, with its abandoned barracks, occupied by Canadian troops during the World War, a beautiful view of the island is obtained, including some prosperous and well-kept cane fields. As far back as 1650 tobacco,

ginger, and cotton were raised here, later to be replaced by sugarcane and coco. "Among all these beautiful islands," wrote Kingsley in "At Last," "St. Lucia is, I think, the most beautiful."

The most easterly of the West Indies is the low coral limestone island of Barbados, "the land of abiding sunshine," exposed to the full force of the northeast trades, famous for its remarkably equable and healthful climate. In contrast with the volcanic islands, the maximum elevation in Barbados is under 1,200 feet. Early devoted to sugar cultivation, the English planters of "Little England" developed large sugar estates and made fortunes. And Barbados, although it has suffered financially from the depression in the sugar market, has managed to remain more prosperous than many of its sister islands. Ninety per cent of the land under cultivation at the present time is devoted to sugarcane, but during the past few years there has been increasing planting of vegetables (tomatoes, potatoes, carrots) for the Canadian market. The fact that there is little or no individual ownership of land by peasant proprietors has forced the negro laborer to be dependent for his livelihood on work provided on the large estates. Where the West Indian negro has his own field to cultivate, he manages to survive with a minimum amount of labor.

Bridgetown lies on the shore of an open roadstead (Carlisle Bay) on the southwest of the island. It has always been a crossroads for marine traffic. Here Washington, with his brother Lawrence, stayed in 1751. Well known in the history of meteorological observations are the rainfall records, kept several decades past, at numerous stations in Barbados. These observations were undertaken in connection with the cultivation of sugarcane, and Governor Rawson's discussion of them in making forecasts of the sugar crop became a meteorological classic. A stay of several hours in the harbor of Bridgetown gave an opportunity, not provided on two previous visits to Barbados (1908, 1910), of taking a motor ride of many miles through the wonderfully cultivated country districts, of which the tourist who spends his time shopping in the city or bathing at the Aquatic Club has no conception. Sugar has long been king in Barbados, and in spite of the depression now existing in the sugar market still holds almost undisputed sway in the island. It was a typical Barbados day, with fleecy cumulus clouds traveling rapidly in the wind, with several short but heavy tropical showers to give variety to the scene, and with the soft trade blowing steadily. For mile after mile there were fields of sugarcane, waving in the wind, dotted with sugar factories and native villages, and here and there one of the original planters' country estates, inclosed by high stone walls, and surrounded by groves of mahogany, coconut palms, mangoes, bananas, breadfruit, all enlivened by the brilliant colors of hibiscus, bougainvillea and other tropical flowers. Very picturesque are the old stone towers of the windmills of earlier days, testifying to the importance of the strong and steady trades, and now unfortunately replaced by buildings containing modern machinery run by steam power. Indian corn, sweetpotatoes, cassava, yams, and other crops gave a pleasing variety to the scene, and from the occasional slight elevations wonderful views of the ocean, and of the trade surf rolling in on the windward coasts, combined to make a picture not easily forgotten.

Barbados is so low an island that the trades sweep across it with hardly an obstruction and with scarcely diminished velocity. Every tree of any height at all is wind blown, and every variety of distortion of trunk and branches and crown may be seen. The traveler on the deck of his steamer in Carlisle Bay may well rejoice that Barbados is flat, for across the bay at all times the strong trade wind brings refreshing relief after the hot streets of Bridgetown. Temperatures taken on board ship, at various hours during the day, varied only from 81.5° to 84°. On the return voyage at Barbados the temperature on board ship was below 85°, and the radio news reported a hot wave with a maximum of 97° in Boston.

St. Vincent has been described as one of the loveliest and least known of the Lesser Antilles. Its volcano, Soufrière, in the eruption of 1902, caused the loss of over 2,000 lives. Another famous historical eruption occurred about a century earlier (1812). Ashes from St. Vincent fell on Barbados, about 100 miles to windward, not, as a well-known West Indies guidebook explains the phenomenon, because of the terrific nature of the explosion, which drove the débris against the trades. At Kingston, the capital and chief port, the mean annual range of temperature is only 3.5°. The botanical garden, small but well cared for, claims to be the first of its kind established in the Americas for the propagation of plants "useful in medicine and profitable as articles of commerce, and where nurseries of the valuable productions of Asia and other distant parts might be formed for the benefit of His Majesty's colonies." Breadfruit, introduced in 1793, has prospered greatly. Cloves were brought from Martinique in 1787 and nutmegs from Cayenne in 1809. The tourist who sees only the port of Kingstown and the charming view of the wooded hills and cultivated fields from Fort Charlotte would never suspect the presence of volcanic activity as recent as that of 1902. The fact that the rainy season was beginning was emphasized by overcast skies and frequent showers. The maximum temperature on shipboard was 83.5°.

Grenada, the last and southernmost of the volcanic Caribbees (lat. 12° N.), has been called "the Spice Island of the West." Cocoa and spices here replace sugar, and fresh fruits and vegetables are shipped to Barbados and Trinidad. The Grenadians boast of the fact that Trinidadians come to Grenada in search of a cooler climate than their own. St. George, with its steep and narrow streets, sometimes terminating in a flight of stone steps, recalls many Italian cities. The local newspaper contained two advertisements which were of interest. One read: "Be prepared for the rainy season," and recommended raincoats, mackintoshes, tweed overcoats, and galoshes. The other bore out the reputation of Grenada as the "spice island" in the notice: "Be sure to get the best value for your cocoa, nutmegs, and mace by selling to —— & Co. (Ltd.)."

TRINIDAD

Physically, Trinidad (1,750 square miles), belongs to South America. The two east-west mountain ranges which border it on its northern and southern margins are a continuation of the northern and southern ranges of Venezuela. These mountains almost inclose the Gulf of Paria, which separates Trinidad from the mainland. The narrrow straits on the north and south are the famous Dragons Mouth and Serpents Mouth. Through the Dragons Mouth (an imposing gateway) Columbus sailed when he discovered Trinidad, and through that northern gateway steamers now pass on their way to and from Port of Spain, "the Queen City of the Antilles," situated on the gulf at the northwestern corner of the island. In these narrow straits the mountain ranges are submerged, leaving a navigable channel. As one writer has expressed it, here "the long attenuated finger of Venezuela points

to the British Colony." Seen from the ocean, or the Gulf of Paria, Trinidad does not differ much in general appearance from the other islands, although none of its mountains are as high as the higher volcanic peaks of the Lesser Antilles. Nor are the products of the soil different. Sugar, molasses, rum, cocoa, coconuts, copra, etc., are leading articles of export. The famous "Pitch Lake" at La Brea has been known from early days. Here Sir Walter Raleigh, in 1595, secured pitch for calking his ships, and here the buccaneers also calked their ships. This asphalt lake covers about 90 acres; and although enormous quantities of asphalt have been removed, there seem to be no signs of exhaustion. The trip to the Pitch Lake was easily made by automobile from San Fernando, where the steamer called for cargo (sugar). An excellent asphalt road takes the traveler through a large sugar plantation, groves of coconut palms, and tropical forests, interspersed with many picturesque, if squalid, collections of huts inhabited by East Indians. Before reaching La Brea an oil field is passed through, with the somewhat novel sight of oil derricks standing in a tropical jungle. The lake itself, with its gray surface covered here and there with pools of water, is disappointing. On the other hand, there is the interest of its immense value, of its inexhaustible supply of asphalt, of the well-kept grounds and buildings of the company, and of the endless chains of buckets which carry the barrels of asphalt directly onto the jetty and load them onto the waiting steamers. Heavy tropical showers fell at intervals and the "patchy" character of the rains could easily be noted by the succession of wet and of dry sections of the road. Under overcast sky, after a thunderstorm off San Fernando, the temperature fell to 80.5° from 85° (2 p. m.). The local newspaper reported that the La Brea district was swept by a severe rainstorm and that the entire Pitch Lake was under water.

Trinidad, about 10° north of the equator, inevitably has a truly tropical climate, moderated by the trades. Port of Spain has a mean annual temperature of about 77°. January (about 75°) is the coolest month, and May the warmest (about 79°). The highest temperatures come before the rainy season, as in a monsoon climate. Extremes at Port of Spain are 100.4° and 57.2°. Relative himidity is always high, over 80 per cent in the rainy and about 75 per cent in the dry season. The rainfall is heaviest (over 120 inches) to the east of the northern mountains, and least (under 60 inches) on the shores of the gulf, on the west. The "rainy season" comes between June and December, with a primary maximum from June to August and a secondary in November. No month is wholly dry. The trades are distinctly weakest in the rainy season; in the dry season of "winter" they blow with full strength all across the island. Where freely exposed to the trades, cocoa trees are protected by wind breaks.

An umbrella was doubly useful during the few hours spent ashore at Port of Spain as protection against a very hot sun and again during the sudden tropical showers which fell at intervals. A visit to the local Weather Bureau station on the roof of the building of the harbor constabulary gave opportunity to look over the daily records and the sheets of the self-recording instruments. At noon, the hour of the visit, the dry bulb in the shelter was 88°; the wind very light from northeast. On the previous day the official readings were: 7 a. m., dry 74°, wet 73°; 3 p. m., dry 87°, wet 80°; maximum, 88°; minimum, 71°. A wet-bulb reading of 80°, it may be noted in passing, has been set by one writer as the limit beyond which physical labor by the white race is impossible. On the return voyage the official readings at Port of Spain were as follows: 7 a. m., dry 72°, wet 71°, 3 p. m., dry 79°, wet 77°; maximum, 89°; minimum, 71°; bright sunshine, 5 hours 38 minutes; wind, northeast. The damp heat of "summer" is very trying, certainly to a northerner. The "winter" months are surely more bearable, because of a lower sun, stronger trades, and cooler nights. Respect for the sun is shown by the fact that automobiles are parked on one side of the street before noon and on the opposite side after noon, the parking side being the shady one. The botanical gardens are very fine and beautifully kept up. The varieties of trees and plants of economic value are surprisingly large. Indeed, one need not go to the primeval forests of Trinidad, so wonderfully described by Kingsley in At Last, to see examples of all the important native forest trees.

Sailing from Port of Spain in the late afternoon, the passage through the Dragons Mouth gave wonderful views of the Venezuelan mountains on the west and the Trinidad mountains on the east, covered with heavy cumulo-nimbus clouds. Later, the surf dashing against the rocky shores of the north coast of the island and the dark rain squalls moving across the hills showed clearly enough why the windward coasts are so deserted and why they are still so heavily forested. Here the trade wind, not man, is master.

DEMARARA (BRITISH GUIANA)

The casual traveler who spends a day or so in Georgetown (Demarara) can see nothing of the great hinterland of British Guiana, with its plateaus and mountains, its vast primeval forests with their variety and abundance of animal, bird, plant, and insect life, its open savannas, its great rivers, its cataracts and waterfalls, its wealth of diamonds and gold and other valuable minerals, and its famous Mount Roraima. The flat alluvial coastal lowland, a narrow strip only a few miles in width, "was once nothing more than a mangrove swamp in front and a sedgy morass behind." The Dutch, the first European owners of the country, reclaimed most of the low coastal belt by means of sea walls, dykes, and dams and laid it out in sugar and cotton plantations, crisscrossed by canals and drainage ditches. Cotton was long ago abandoned and sugar became king. This coast, reclaimed from the sea and the forest, is practically the only inhabited and cultivated part of British Guiana, "the Golden Crown of South America," where Sir Walter Raleigh sought his El Dorado.

Georgetown, or Demarara, lies on the right bank of the Demarara, at its mouth, and also has frontage on the ocean. Lying below sea level at high tide, it is protected by a massive sea wall and is drained by canals and sluices, pumped by steam. The houses are raised above the ground on stone, concrete, or wooden posts. For at least two hours before reaching port the ocean is discolored by the mud brought down by the numerous rivers supplied by the heavy rains. "Few countries on the surface of the globe," wrote Sir R. H. Schomburgk, "can be compared with Guiana for vigor and luxuriance of vegetation. A constant summer prevails, and the fertility of the soil, the humid climate, and a congenial temperature insure a succession of flowers and fruits; in a person accustomed to the sleep of nature in the northern regions, where vegetation is deprived of its greatest charms, the leafy crown and the fragrant blossoms can not but raise astonishment and admiration."

The hot, steamy atmosphere of the Guiana coast is not exactly a white man's climate. By means of inden-

tured East Indian coolie labor, a plan now abandoned, the cultivation of sugar cane was here brought to a high state of perfection and of financial profit. With the lack of forced labor and the depression in the sugar market, British Guiana is turning more and more to rice and other crops under the skillful and tactful guidance of the agricultural department.

Meteorological observations have been kept at Georgetown (lat. 6° 50′ N.; long. 58° 12′ W.) for many years, first at the observatory and later (since 1882) in the botanical garden. The mean annual temperature is between 79° and 80°, with an annual range of 2.3°. The mean maxima range between 83° and about 87°, according to the season, and the mean minima between 74.°7 and 75.7°. The absolute maximum is 91.9°; the absolute minimum, 68°. The rainfall is heavy (85 inches in round numbers), and there is a double rainy season, May-August and December-January, with a long "dry" season in September-October and a short "dry" season in February, occasionally in March or April. Calms and light variable winds are most frequent in the primary wet season, which is normal and obviously controlled by the equatorial rain belt. The "winter" rainy season is abnormal and puzzling and its explanation has been much debated. The prevailing winds in the "low-sun" season blow more steadily and more directly on shore (northeast trades). The mean monthly rainfalls in June and in December are 12 inches and 11.5 inches, respectively, and in September and October 2.75 inches and 2.36 inches, respectively. The fact that during so much of the year the wind is on-shore is a great boon to Georgetown. The number of rainy days is 23 to 24 in June, 20 in December, 16 to 17 in February and March. The relative humidity is always high (75 to 80 per cent). Hurricanes never occur and high winds are very rare.

When one thinks of the Guianas there inevitably come to mind the horrible stories of the excessively high death rates among the convicts in French Guiana. As some one has said, "French Guiana was conveniently endowed with an unhealthy climate," and another has written: "Perhaps it is its fatal climate which has won for French Guiana its chief fame as a convict settlement." It is true enough that the disease and death rates in all the Guianas have in the past been alarmingly high, but "the man behind the climate," in British and Dutch Guiana especially, is winning out by means of modern sanitary and medical precautions. So successful has been the fight that Knoch has recently written, "to-day life on the coast, from the standpoint of health, offers no special dangers." That the steady "hothouse" air and the heavy rainfall are very trying to white men there is no doubt, but with free exposure to the wind, protection against the sun, and reasonable precautions life is not precarious.

Two of the most profitable and interesting days of the trip were spent in Georgetown. Through the courtesy of the agricultural superintendent of British Guiana, Mr. Peterkin, the many activities of the department of agriculture were fully explained. About 60 acres in connection with the botanical gardens are devoted to the experimental cultivation of many varieties of rice and of other crops. Thoroughly up-to-date methods of the selection and treatment of the different crops are employed in laboratory and field. The remarkable herbarium of British Guiana plants was also visited, and a leisurely inspection of the meteorological station, now located in the botanical gardens, well repaid the trip to Demarara. Windvane and 4-cup anemometers, self-recording, are on the roof of the 2-story building which also houses the herbarium. The Richard barograph is on the ground floor, as is the thermograph, the latter in a window shelter. Outside, in an inclosed rectangle, are the various outdoor instruments; the thermometers, wet and dry, in a Stevenson screen; evaporation tank; soil thermometers; radiation thermometer; Campbell-Stokes sunshine recorder; black bulb in vacuo; ordinary 8-inch gage and a Negretti and Zambra hyetograph. The exposure is excellent. One of the two days in Georgetown brought several short, light showers, and one heavy rainfall of about 0.80 inch in an hour and a half, accompanied by a sharp squall. The second day was clear to fair without rain. The heat was intense, but was relieved whenever there was a breeze, and beginning about sunset there was enough cooling to be noticeable and refreshing. On the day of landing the official record was as follows: 6 a. m., 74°; noon, 85°; 6 p. m., 81.5°; midnight, 81.0° maximun, 87°; minimum, 73°; maximum in sun 148°; minimum temperature on grass, 72°; wind velocity, 8 a. m. to 6 p. m., 4.5 miles an hour; 6 p. m. to 8 a. m., 1.78 miles an hour; maximum velocity, 7.5 miles an hour; rainfall, 12:05–12:10 p. m., 0.17 inch. On the following day the incomplete record showed: 6 a. m., 77°; noon, 79°; maximum, 85°. These few data serve to show the general character of successive days near the close of the primary rainy season in Demarara. The only appreciable variation from day to day is in the amounts of rainfall.

The return voyage from Georgetown gave opportunity to renew acquaintance with the weather types and climatic controls noted on the outward voyage. From Georgetown to Bermuda the barograph curve rose very slowly, day after day, on the weak pressure gradients, the highest reading (about 30.10 inches uncorrected) being recorded at Bermuda. The diurnal variation continued to beyond latitude 30° N., and faded away in the Bermuda area. Near the northern limits of the northeast trade calms were encountered and continued to Bermuda. The percentages of calms in the "squares" south and east of Bermuda in July are fairly high (15 to 19 per cent), as is to be expected on the weak pressure gradients over that part of the ocean. The two days in the westerlies between Bermuda and Boston brought a characteristic "temperate" zone variety of weather: Variable winds, mostly southwesterly, the first westerly winds in a month; mostly overcast skies; an early morning thunderstorm; near the New England coast some fog, the first fog since leaving this same area on July 9. The temperature, which had remained steadily over 80° on board ship throughout the voyage, fell below that point with fresh northeast winds a day west of Bermuda. Martinique, passed at night on the outward voyage, was clearly seen on a bright afternoon on the homeward trip. Great cumulus masses covered the mountain tops and rolled down the leeward slopes. Not until the ship was to the north of the island could the "steam-smoke" column rising from the summit of Mont Pelee be clearly seen. The vertical height to which this column rose varied. The top of it was turned to the westward by the trades.

Addendum.—The foregoing account of my month's cruise among the Lesser Antilles hardly includes all that was found in the way of meteorological and geographical interest. It is my chief hope that what I have written may stimulate some of my fellow teachers to go "weather hunting" away from home.

THE GENESIS OF A TROPICAL CYCLONE

By FRANKLIN G. TINGLEY

Foreword, by Willis E. Hurd.—After Mr. Tingley's death there was found in his desk the substance of the following article. It was preeminently true of its writer that he exercised a great amount of caution in the preparation of any text out of the routine for publication, with characteristic gentleness and shyness preferring to withhold its appearance in type until his ground for statements was completely laid out, solid, and satisfactory. Originally intended for publication in the MONTHLY WEATHER REVIEW, in conjunction with some related notations and analyses prepared by L. T. Chapel, of the Hydrographic Office at Cristobal, the Genesis of a Tropical Cyclone was apparently in the main complete, though it required some rearrangements and amplifications. These changes have been undertaken sympathetically by the writer of this foreword, with the feeling and hope that they would not have been unacceptable to his former division chief, from whom, in connection with his own studies and writings, he had always received the most sympathetic and helpful consideration.

The locality and some of its meteorological features.—About the middle of October, 1926, a cyclone of great importance formed in the southwestern part of the Caribbean Sea, where that body of water extends southward to the Isthmus of Panama. This extension is in the form of a large embayment extending some 700 or 800 miles southwestward from the main body of the Caribbean and having at its southern extremity the Mosquito Gulf on the Central American side and the Gulf of Darien bordering on the South American mainland. This part of the Caribbean lies between the region of the northeast trade winds of the Atlantic and that of the south to southwest winds of the extreme southeastern North Pacific. It is a zone marked by a large percentage of calms, the 5° square bounded by the tenth and fifteenth parallels and the eightieth and eighty-fifth meridians, in which the cyclone originated, having a percentage of 22. The bordering 5° squares show percentages as follows: North, 14; east, 12; south, 25; west, 37. The frequency of calms, as well probably as the existence of oppositely directed winds on either side, makes it a region favorable for the formation of cyclones. Indeed, one may well ask the question, Why do cyclones not form here in greater numbers?

While the meteorological features of the region, including the Isthmus of Panama and adjacent territory, have been very fully studied in recent years, it is desired to emphasize the annual changes that occur in the wind régime at the Isthmus as shown by the records of the Colon Observatory. An article by L. T. Chapel, of the Hydrographic Office, Cristobal, published in the MONTHLY WEATHER REVIEW for December, 1927, (1) deals very fully with wind conditions in the Panama area, and two diagrams which appeared in that article show the annual march of wind frequency and velocity at Colon and also at Cape Mala, 113 miles to the southward.

Inasmuch as something like three-fifths of the tropical cyclones that form in the western Caribbean occur in October and November, the behavior of the winds at this season of the year has a special significance. The diagrams referred to show clearly the decline in the frequency of northerly winds, which reach a minimum in October, and the concurrent decrease in velocity. Data are not adequate to show how far northward over the waters of the Caribbean this seasonal reversal of condition extends, but it appears likely that the area embraced includes that in which the majority, if not all, of the autumn hurricanes of this region have their origin.

In the general region of the western and southwestern Caribbean some 54 cyclones have had their origin in the past 44 years, or during the period 1887–1930, of which number 23 are known to have attained hurricane intensity. Out of the total some 22 have probably formed in approximately the same region as the one particularly under consideration, namely, that of 1926. Information, however, is not clear on this point in every instance. Of the extreme southwestern group, 10 occurred in October, 5 in November, 4 in September, 2 in June, and 1 in July.

Another preliminary meteorological fact is here well worth noting. Mitchell (2) has shown that tropical cyclones of the West Indies and North Atlantic Ocean develop principally in two general regions, one of which is the western Caribbean Sea; the other, the eastern part of the ocean near the Cape Verde Islands. In these localities, especially during specific periods, doldrum conditions in the North Atlantic are most fully developed. The existing records, extending now over many years, fail to show conclusively that any tropical cyclone has originated in the eastern part of the Caribbean Sea or adjacent areas of the Atlantic, and in this connection it may be explained that the tracks of tropical cyclones as depicted on the various charts start in many instances where the storm was first observed, perhaps fully developed, and that in some cases at least it is impossible to track the cyclone to its place of origin owing to lack of observations.

Ship and land observations in the southwestern Caribbean.—A distinguishing feature of this specific region, and one that merits the attention of students, is its favorable situation for the securing of observations. It is on this account one of the best suited of all bodies of water for the study of embryonic tropical cyclones at the present time, since many more observations are potentially available from this part of the Caribbean Sea than from almost any other originating locality. In recent years the greater part of the growth of shipping here, and therefore of potential weather observations, is, of course, due to the construction of the Panama Canal, which was opened to traffic in 1914. But a part also results from the development of the tropical-fruit industry and other South and Central American resources.

A circumstance that makes the early history of the 1926 cyclone of more than ordinary interest is the unusually full number of vessel observations available for the region and period of formation, as well as some highly interesting observations from near-by coastal stations. While even this number is not so numerous and well placed for study as could be wished, nevertheless it constitutes the best series on record covering the incipient stages of a tropical cyclone in these, if not in other, waters.

The land observations comprise those from the first-order stations at Colon and Balboa Heights, Panama Canal Zone, and Bluefields, Nicaragua. Compilations of wind and barometric data for the first two stations for the period October 13–20, 1926, kindly prepared by R. Z. Kirkpatrick, chief of surveys, the Panama Canal, appear herewith as Tables 1 and 2. Data for Bluefields for October 12 to 18, inclusive (7 a. m. and 7 p. m., seventy-fifth meridian time), are shown in Table 4. A record of pilot-balloon flights at the United States naval air station at Coco Solo, Canal Zone, near Colon, distant about 150 miles from the point of origin of the hurricane, appears in Table 3.

Formation and development of the storm.—The history of the hurricane in question of 1926 may be said to have

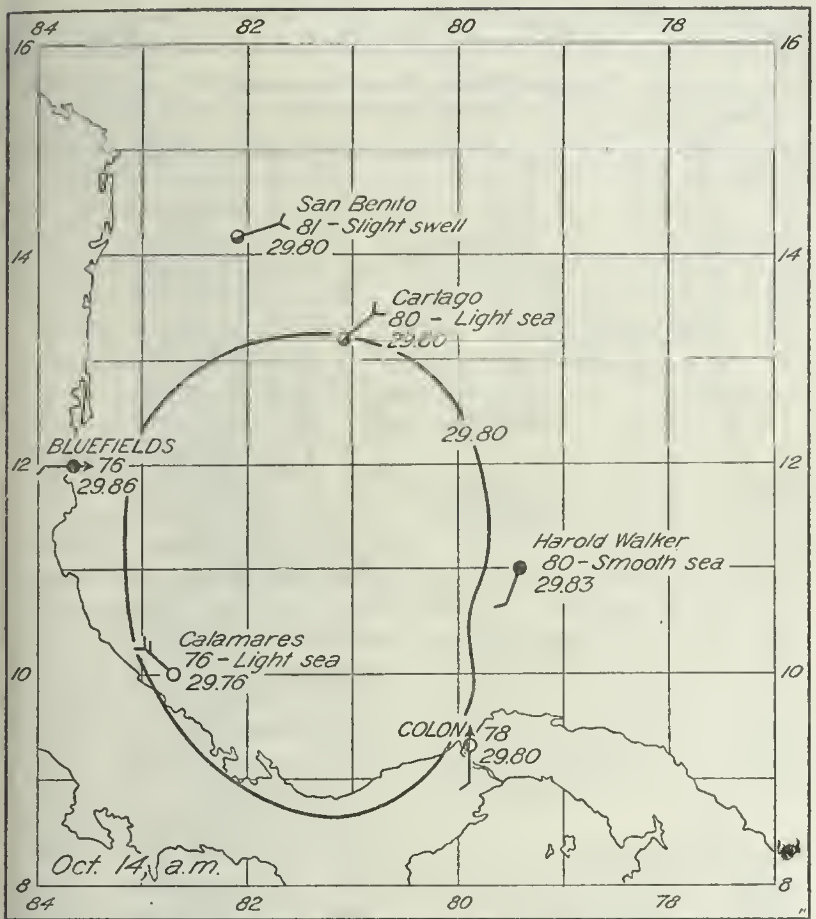

FIGURE 1.—Pressure and wind conditions at 7 a. m. of October 14, 1926

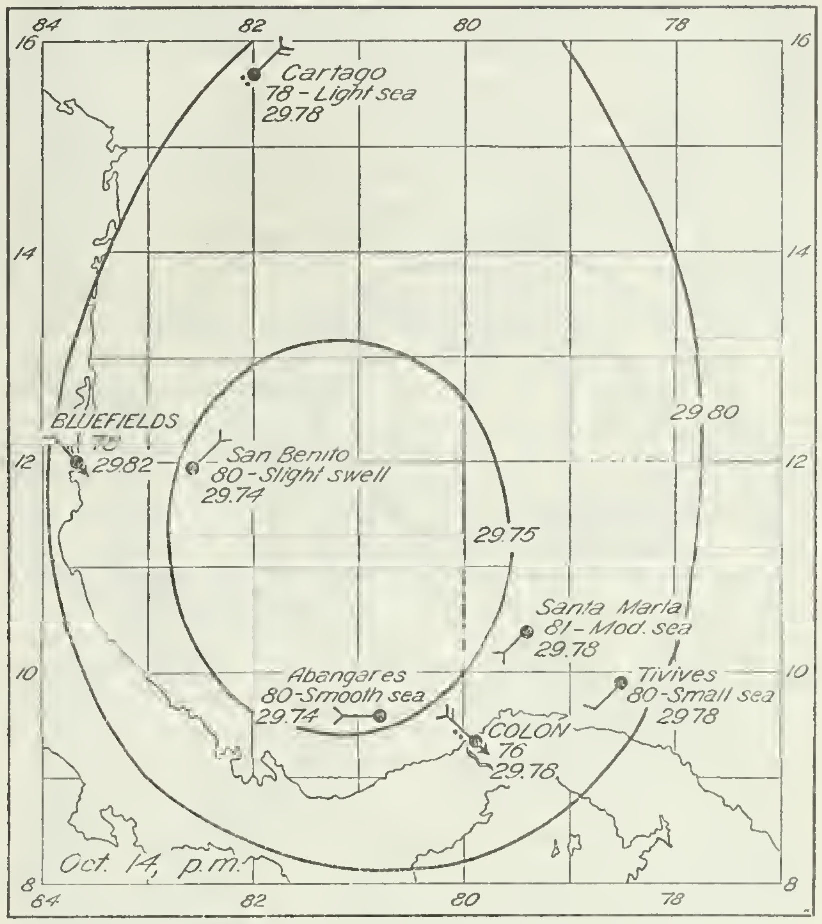

FIGURE 2.—Pressure and wind conditions at 7 p. m. of October 14, 1926

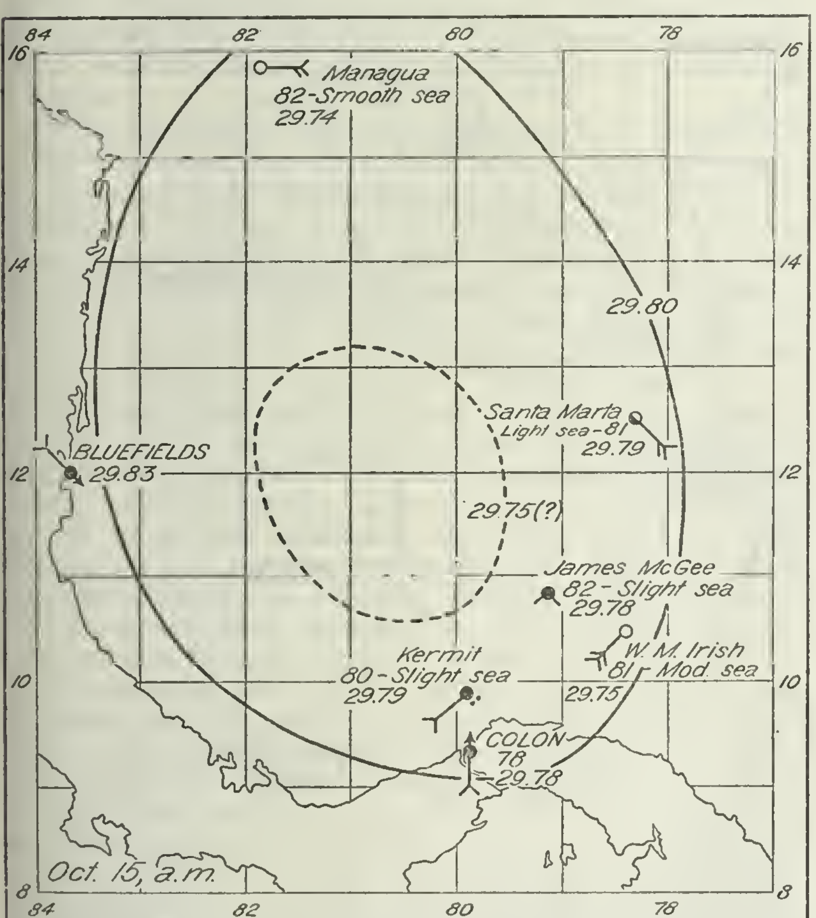

FIGURE 3.—Pressure and wind conditions at 7 a. m. of October 15, 1926

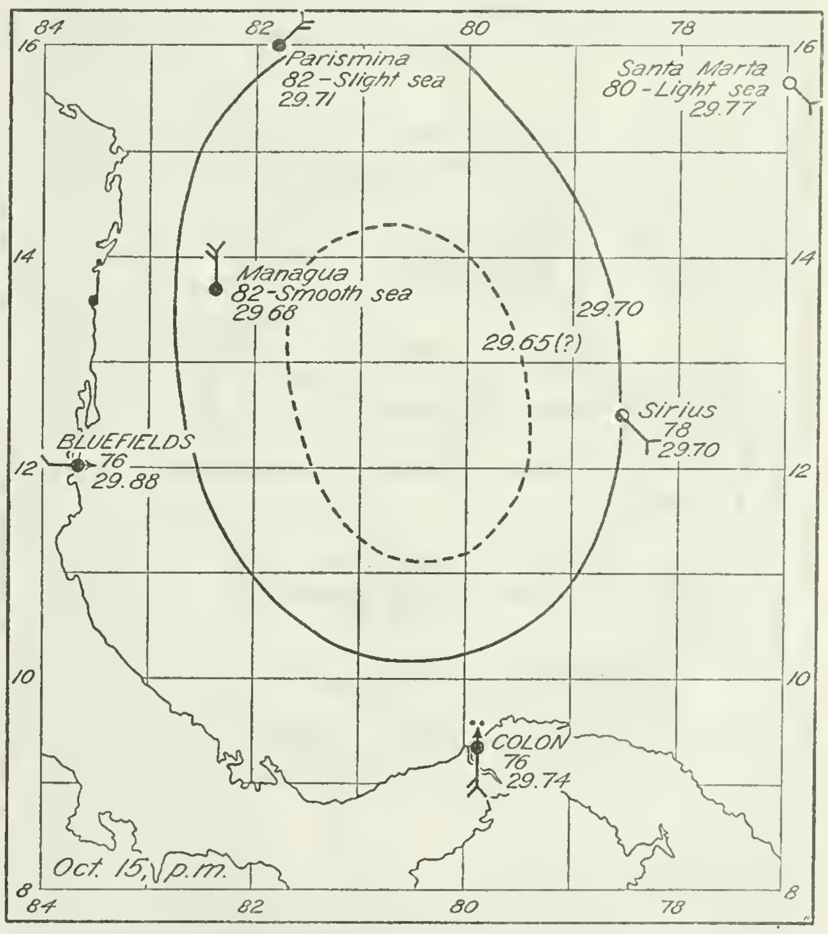

FIGURE 4.—Pressure and wind conditions at 7 p. m. of October 15, 1926

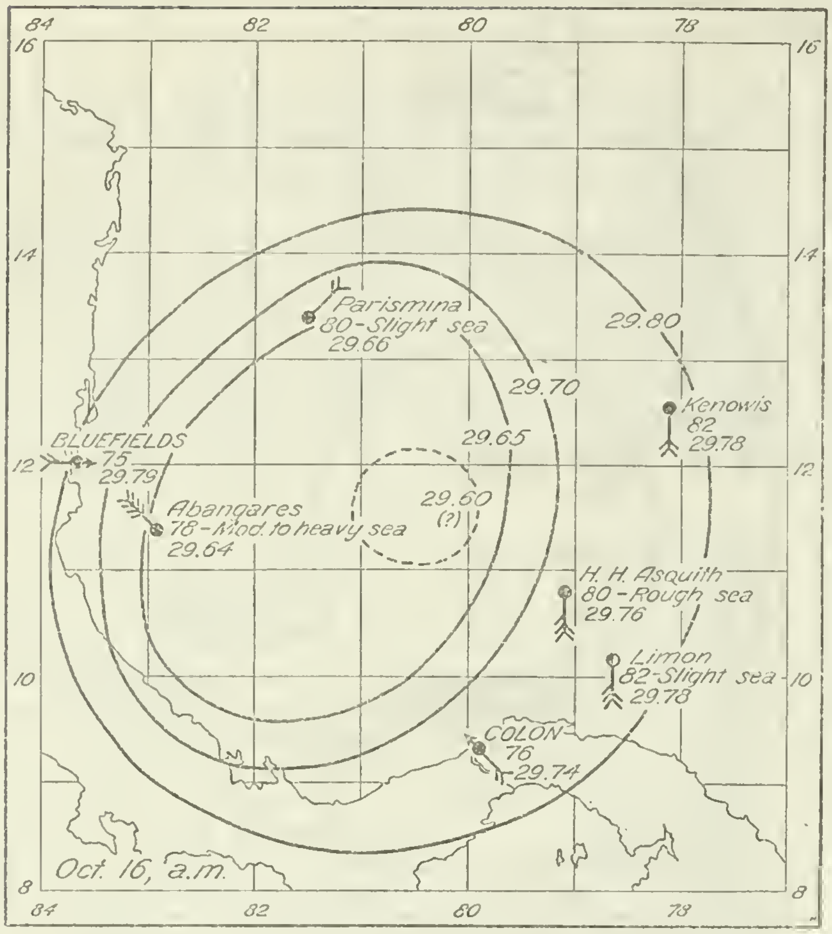

FIGURE 5.—Pressure and wind conditions at 7 a. m. of October 16, 1926

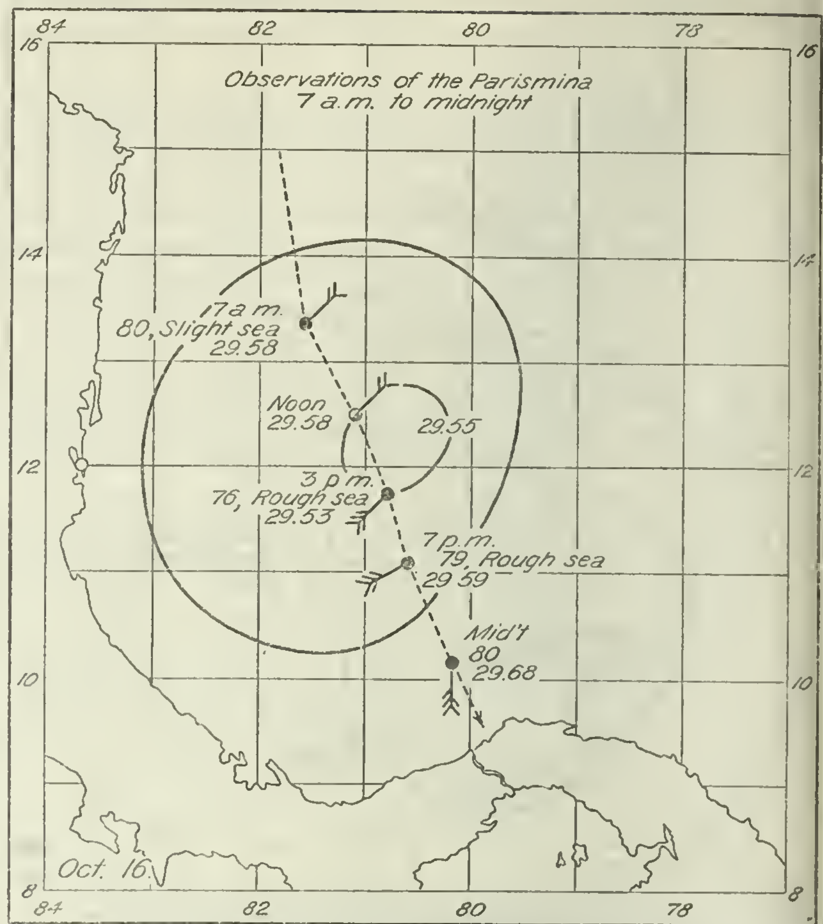

FIGURE 6.—Observations of the S. S. *Parismina*, 7 a. m. to midnight of October 16, 192

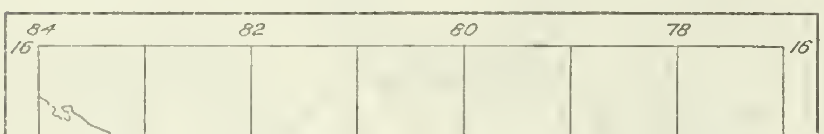

FIGURE 7.—Pressure and wind conditions at 7 p. m., of October 16, 1926

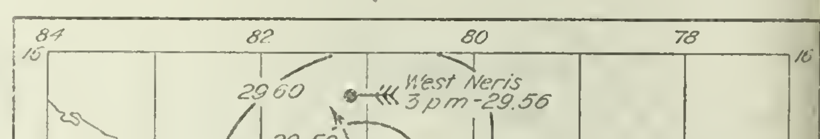

FIGURE 8.—Track of the tropical cyclone for the formative period, October 14-17, 1926. (The entire track will be found on Chart II, Monthly Weather Review, October, 1926)

begun on October 13, when a gentle cyclonic circulation was indicated by the vessel observations in that part of the Caribbean Sea already described as adjacent to the Isthmus of Panama. On the following day a small but general fall in pressure was noted as having occurred over the same area. The normal pressure over this region for the hour of 7 a. m. (seventy-fifth meridian time), at which hour the morning vessel observations are taken for the Weather Bureau, is 29.86 inches. At 7 p. m. pressure is normally slightly lower, 29.83 inches at Colon and 29.78 inches at Bluefields (Nicaragua). On the morning of the 14th the average of the station readings at these two places was 29.84 inches, 0.02 inch below normal, and that of four vessels in the general vicinity, 29.78 inches, or 0.08 inch below normal. The position of these vessels is shown on Figure 1.

On the morning of the 15th the average pressure at the two stations named was 29.81 inches and that of three reporting vessels 29.80 inches. By 7 p. m. of the 15th pressure at Colon had fallen to 29.74 inches, 0.09 inch below normal. At the same hour the average of the barometer readings of five vessels south of the sixteenth parallel was 29.72 inches, some 0.11 inch below normal. On the other hand Bluefields at this hour reported a pressure of 29.88, or 0.09 inch above normal, so that the gradient between that place and the center of low pressure, about 250 miles to the east-southeastward, was 0.18 inch, a significant value for the region.

While this slow fall in pressure was taking place the reports from ship and shore stations showed a gentle southerly wind at and north of Colon, while at some distance farther to the northward, about 300 miles, it was easterly and northeasterly, light to gentle as a rule. On the Nicaragua side light to gentle westerly winds prevailed. With the evidence presented by wind and pressure it required only a slight stretch of the imagination to place a weak cyclonic center somewhere to the north-northwest of Colon.

By the morning of the 16th cyclonic activity showed a further increase, pressure having fallen about 0.05 inch, and the wind had freshened about two points, Beaufort. Bluefields pressure was now at 29.79 inches, 0.08 inch below normal, while 75 miles to the southeastward the steamship *Abangarez* reported squally weather with rain; barometer 29.64 (−0.22) inches; wind NW., force 8; moderate to heavy sea. The conditions at this time are shown on Figure 5.

The strong wind movement off the Nicaraguan coast, reported at this time by the *Abangarez*, and 12 hours later by the *Managua*, is probably explained by the occurrence of local squalls. The observers on these vessels did not make any entries in the Daily Journal. The observer on the *Abangarez* described the weather at time of observation in the following Beaufort notation, *o. z p. q.* (overcast, haze, passing showers, squalls); the observer on the *Managua* entered merely, *o.* (overcast).

Between noon and 3 p. m. on the 16th the steamship *Parismina*, southward bound, passed through the western part of the cyclone area, the barometer falling to 29.53 inches (0.33 inch below normal) and the wind shifting from northeast to west-southwest. The sea meanwhile had increased to rough. The observations from the *Parismina* (fig. 4) probably represent close to the maximum conditions of intensity developed by the cyclone at that period. It is not apparent that much change in the location of the center had taken place between noon and 3 p. m. of the 16th, and the center at the latter hour may be placed close to latitude 12° 30′ N., longitude 80° 30′ W. From that time, however, there was a slow but steadily increasing movement of the center in a direction about north by west.

The next report to be received from a vessel in close proximity to the center was one from the steamship *Pastores*, the observation being made at 3 p. m. of the 17th in about latitude 14° 20′ N., longitude 81° 30′ W. At this hour the pressure at a point which could not have been far from the actual center of the depression was 29.42 inches, representing a fall of slightly more than one-tenth of an inch in 24 hours. Thus during the day elapsing between the observation from the *Parismina* on the afternoon of the 16th, and that from the *Pastores* on the afternoon of the 17th, the center of the gathering storm had advanced an approximate distance of 150 miles.

At noon of the 18th, 21 hours later, the mid-point of the cyclone had reached latitude 16° 30′ N., longitude 82° 30′ W., distant 300 miles from the place of origin, and had developed winds of force 11–12, as determined from the report of the American steamship *Atenas*. This vessel, Capt. E. W. Holmes, observer J. A. MacCabe, bound from New Orleans to Cristobal, was in the actual center of the storm at mid-day of this date. And it may be observed that Captain Holmes holds the extraordinary record of having obtained a noon position by observation of the sun when in the "eye" of a tropical hurricane.

The history of the storm subsequent to October 18 has been covered in another article (3) and will not be further considered here, beyond the statements that its center passed over Isle of Pines and western Cuba on the 19th and 20th, where it caused great loss of life and enormous damge to property, and thence, pursuing a northeasterly course, it crossed the Bahamas and on the 22d passed near Bermuda, where it caused the loss of H. M. S. *Valerian* and the British steamship *Eastway*, with regrettable loss of life. Between the 24th and 29th it performed an extensive right-hand loop in midocean, a feature of the hurricane that is very fully treated in the article mentioned.

The 8 charts in series presented herewith give as full details of atmospheric and sea conditions over the southwestern Carribean during the 14th to 17th as may be obtained from such regular and special weather observations as are at hand for the period. Supplementary details of observations are added to these from the weather logs of reporting vessels.

Discussion.—Of all the features associated with the development of this cyclone, possibly the most interesting and significant is that of the strengthening of the southerly winds at the Isthmus of Panama. This is well shown by the records appearing in Table 1. Inasmuch as in several other instances accelerated wind movement at the Isthmus has coincided with the early increase in intensity of tropical cyclones over the neighboring waters of the Caribbean, a relationship between the two occurrences is strongly suggested, notwithstanding the fact that similar acceleration has been lacking in some cases. It is not yet certain, however, whether the relationship, if real, is one of cause or effect. It appears fairly certain that in the case of this hurricane of 1926 a gentle but nevertheless true cyclonic circulation had become established over the Caribbean before any appreciable change in wind movement was noticeable at Colon. This points to local convection unaided—or should it be put, unimpeded—by extraneous air movement. Chapel has shown diagrammatically (1) that, on the average for the cyclones first reported south of latitude 15° N., the maximum frequency of southerly winds occurs on the second day of the storm's known existence as such. The fact that cyclones here form most frequently during October, when southerly

winds at Colon attain a maximum of frequency, would indicate that such winds are necessary in most if not all cases to cyclonic development.

At this point it will be illuminating to quote from Chapel on the relation between southerly winds and hurricane formations. He says:

In a comparison of southerly winds at Colon with the time of hurricane formation it is noted that for storms first reported north of latitude 15° the maximum of southerly winds at Colon usually precedes the first report by one or two days; but for storms originating south of latitude 15°, or within 300 miles of Colon, the maximum usually occurs on the day of reported formation or the day following. In other words, as far as the near-by storms are concerned, a cyclonic circulation actually exists and has been identified as such before the maximum of southerly wind occurs at Colon.

A comparison of all available records at Colon and Cape Mala indicates that the initial momentum of these southerly winds originates somewhere in the South Pacific, and that they extend northward with diminishing velocity, and are entirely independent of the existence of any cyclonic formation. According to fishermen and turtlers familiar with the southwestern Caribbean, the most obvious feature locally at the time of the formation of a tropical cyclone is frequently the southeast gales that persist, sometimes for several days, after the storm has passed. It would appear that the existence of a following wind in the wake of the moving storm, but distinct from the cyclonic circulation itself, is a reality, and that the influence of this wind in intensifying the already existing southerly winds over the Isthmus of Panama produces the comparatively high velocities which is their most noticeable feature.

The normal southerly winds at Colon are essentially light, 7 miles an hour on an average for a considerable term of years. The actual average hourly velocities at this place for October 13, 14, and 15, 1926, in advance of the onset of the stronger winds, were 5.8, 7.8, and 7.4 miles, respectively, or exactly 7 for the period. Inasmuch as fully developed cyclones form here on an average of only one every other year, it is apparent that the seasonal condition of light southerly winds must be very completely established and maintained for some time as an antecedent requisite.

In our specific case an advance of the northeast trades on a broad front at any time prior to October 15, such, for example, as occurred in October, 1930, would most probably have broken up the cyclone structure then in existence. On the other hand the fortuitous arrival of a narrow current of equatorial air that had found its way across the mountain barrier to the southward may have contributed the necessary impetus to the circulation.

The observed facts regarding the genesis of this hurricane may be summarized as follows: First, slightly reduced pressure and gentle cyclonic circulation over a region some 300 miles in diameter; second, a slow transition from this state to one of storm intensity, requiring at least three days to develop winds of gale force near the immediate center, although squalls formed locally within the affected area; third, a strengthening of the southerly winds at Balboa Heights, near the Pacific entrance to the Panama Canal, and distant nearly 250 miles from the point where the center was first definitely observed to be located, 24 hours before the center was observed; fourth, a slight increase in wind velocity above the 612-meter level, also before the observance of a center, at the naval air station at Coco Solo, near the Atlantic entrance to the Canal.

The increase in velocity at the Isthmus occurred first at Balboa Heights, at the greater distance from the cyclone center, and nearly the maximum velocity was reached rather abruptly on the 15th, high winds continuing until the 17th. On the Atlantic side, some miles nearer the cyclone center, there was a gradual acceleration to a well-marked maximum on the 18th. This difference in time suggests that the current of higher velocity was flowing at an angle to a line joining the two places, which would run about north-northeast from Balboa Heights. The explanation for the behavior of the wind probably lies in the topography of the Isthmus. It will be noted also that the maximum velocity at Colon was not reached until the cyclone center had traveled away from that place a distance of about 5°, or nearly 350 miles. Thus the wind velocity at Colon is shown as being, up to the 18th, in direct relation to the cyclone's energy, rather than to its distance away.

The record of pilot balloon flights at the Coco Solo Naval Air Station is regrettably marred by a gap embracing the critical dates of the 17th and 18th. This gap was occasioned by bad weather (rain) and the falling of the 17th on Sunday, on which day the morning observation was regularly suspended. It is therefore impossible to say definitely when the increase in wind movement at that place reached a maximum. It will be noted in Table 4 that the average of the velocities at the levels of 1,170, 1,350, and 1,530 meters was substantially the same as that for the lower levels of 216, 414, and 612 meters.

A point to be considered is that at the time of maximum velocity at Colon, that is, on the 18th, the direction of the wind was steadily southeast and apparently unrelated to the cyclonic circulation established to the northward. The reporting vessels, *El Lobo* and *Pastores*, 100 to 125 miles at sea, also were experiencing southeast winds, at variance with the circulation, and it is necessary on the day mentioned to go another 150 miles to the northward to find vessels within the field of the cyclonic circulation. Here are found the *Calamares*, *Limon*, *Managua*, and *San Benito* with southwest or south winds. The persistence of southeast winds after the passing of a cyclone was first brought to attention by Chapel in 1927.

Here the case must rest until additional evidence and further study can be combined to throw a clearer light on the formative processes of hurricanes in this region. A necessary step will be to examine areas of low pressure that form in the southwestern Caribbean and do not result in hurricanes; another to determine whether there are periods of accelerated wind movement at the Isthmus that do not coincide either with such low-pressure systems or fully developed storms. Data on this point are not available for incorporation in the present article.

In the initial stages of formation as here considered, the tropical cyclone is of more interest and moment to the meteorologist than to the mariner. During these stages weather and sea conditions are not yet sufficiently bad to cause concern to the latter and it therefore not surprising that observational details recorded by him are frequently meager. Therefore it may not be out of place here to emphasize the dependence of the student on the facts of observation—including details which must often have little or no apparent significance to the usual observer.

As an example of the type of weather development that may be expected in tropical seas during the early formative stages of a disturbance, the observations of a trained meteorologist during a period of unsettled weather in the Caribbean are of peculiar interest. The following quotation from some unpublished notes by L. T. Chapel will illustrate the point:

A development of this kind from a practically clear sky was observed by the writer on October 24, 1927, from the steamship *Cristobal* bound from Port au Prince to the Canal Zone. The position was 60 to 90 miles east to southeast of the island of Jamaica. At 10 a. m. the sky was almost clear with a few scattered

cumuli motionless near the horizon. Low strato-cumulus began to appear around the ship and shortly thereafter rain began to fall, an "April shower" condition. There were probably a dozen separate showers within view of the ship at once. The showers rapidly became squalls and the clouds piled up. By late afternoon the separate squalls had coalesced and a pall of alto-stratus overspread the west, northwest, and north, apparently a sharply defined cloud mass 25 to 30 miles in diameter and perhaps more, with heavy rain general. The wind was light easterly throughout except when a rain squall passed over the ship.

Following are additional details of observations of the hurricane of 1926 from the weather logs of reporting vessels:

WEATHER AND SEA CONDITIONS

October 14, 7 a. m.

Calamares.—Clear, no clouds; light NW. sea.
Cartago.—Cloudy, passing showers; 5 Cu., NE.; light NE. sea.
Harold Walker.—Overcast, squalls; 9 Cu. N., SE.; smooth (NW.) sea.
San Benito.—Cloudy; 6 Cu. and Ci. Cu., NE.; slight E. swell.

October 14, 7 p. m.

Abangarez.—Overcast, squalls; 9 A. S., W.; smooth sea.
Cartago.—Overcast, rain; 8 N., NE.; light NE. sea.
San Benito.—Overcast; 10 Cu. and Ci. S., E.; slight NE. swell.
Santa Marta.—Cloudy to overcast; 8 Cu. N., SW.; moderate SW. sea.
Tivives.—Cloudy; 7 Cu. N., SW., small W. sea.

October 15, 7 a. m.

Kermit.—Cloudy; 6 Cu., SSW., slight sea.
James McGee.—Cloudy, passing showers; 8 N., var.; slight sea.
Managua.—Cloudy; 3 Cu., E.; smooth (E.) sea.
Santa Marta.—Cloudy, passing showers; 7 Cu. N., SE.; light SE. sea.
W. M. Irish.—Clear to cloudy; 4 A. St., SW.; moderate SW. sea.

October 15, 7 p. m.

Managua.—Overcast; 9 Cu., NW.; smooth (E.) sea.
Parismina.—Overcast, passing showers, good visibility; 10 Ci. S., E.; slight E. sea.
Santa Marta.—Overcast; 9 Cu. N., SE.; light SE. sea.
Sirius.—Radio report only, details shown on chart.

October 16, 7 a. m.

Abangarez.—Overcast and hazy, passing showers and squalls; 10 A. S., NW.; moderate to heavy NW. sea.
H. H. Asquith.—Cloudy with drizzling rain at times; rough S'ly sea.
Limon.—Cloudy; 5 Cu., SW.; slight sea.
Kenowis.—Radio report only, details shown on chart.
Parismina.—Cloudy, passing showers, good visibility; N. and Cu. N., ESE.; slight sea.

October 16

Parismina.—Noon, partly cloudy; light swell. 3 p. m., cloudy; rough sea.

October 16, 7 p. m.

Abangarez.—Overcast, passing showers and squalls, good visibility; 9 Cu. N., NNE.; light NE. sea.
Calamares.—Overcast, rain; 10 Cu. and N., E.; light E. sea.
Managua.—Overcast; 10 Cu., NE.; moderate E. sea.
Parismina.—Overcast with haze, rain, squally; rough sea.

October 17

Managua.—7 a. m., overcast; 10 Cu., NW.; rough E. sea.
Pastores.—3 p. m. Radio report only, details shown on chart.
West Neris.—7 a. m. Overcast, gloomy, rain; 10 Cu. N. and N., S'ly; small S'ly sea; 10 a. m., wind backed from S. to E., fresh; 4 p. m., backed to NE., strong. Experienced low barometer (29.56 inches) in latitude 15° 39′ N., longitude 81° 10′ W. (About 3 p. m., estimated.)

Special mention may be made of the singular experience of the royal mail steamer *Orcoma*, which, after overtaking and passing the gathering cyclone on October 17, while en route from Panama to Habana, was herself overtaken by the cyclone, then a fully developed hurricane, while lying in Habana Harbor on the 20th. The report of the *Orcoma* is taken from the Marine Observer, published by the British Meteorological Office, issue of September, 1927. The speed of the *Orcoma* was approximately 14 miles (statute) per hour. The weather experienced during the 17th was as follows:

4 a. m. Wind S., force 4; barometer 29.75 inches; temperature, air, 78°; overcast, frequent torrential showers; squally, with some thunder and lightning; moderate SSW. swell.

Noon. Position, latitude 13° 53′ N., longitude 80° 09′ W. (D. R.); wind S., 5; barometer 29.68; temperature 78°; overcast with rain; moderate SSW. swell.

3 p. m. Violent squall, force 10 (S.); temperature fell 4.5° before squall, rising again with passage.

4 p. m. Wind S., 6; barometer 29.53 inches; overcast with rain squalls; moderate SW. swell.

8 p. m. Wind S., 5; barometer 29.65 inches; temperature 80°; overcast with rain squalls; heavy SSW. swell.

Midnight. Wind SSW., 4; barometer 29.62 inches; temperature 79°; overcast with rain squalls; heavy SSW. swell.

NOTE.—All of *Orcoma's* barometer readings are corrected for height, gravity, and diurnal variation.

TABLE 1.—*Colon, October, 1926, hourly wind direction and velocity; hourly pressure*

Date	A. M.												P. M.												Mean
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid't	
HOURLY WIND DIRECTION																									
13	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	sw.	w.	w.	w.	w.	w.	sw.	sw.	s.	s.	s.	s.	s.	-----
14	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	sw.	sw.	sw.	w.	sw.	sw.	se.	s.	s.	s.	s.	s.	s.	-----
15	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	s.	s.	s.	s.	s.	s.	se.	se.	se.	-----
16	s.	s.	s.	se.	se.	se.	se.	se.	se.	s.	s.	s.	s.	s.	w.	sw.	s.	s.	s.	s.	se.	se.	se.	se.	-----
17	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	s.	s.	s.	s.	s.	s.	s.	s.	s.	se.	se.	se.	-----
18	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	-----
19	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	-----
20	se.	se.	se.	se.	se.	se.	se.	se.	se.	s.	s.	sw.	w.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	-----
HOURLY WIND VELOCITY, M. P. H.																									
13	3	2	4	4	4	5	5	5	7	6	7	11	13	10	5	4	5	5	7	5	4	6	6	6	5.8
14	8	6	5	5	6	5	5	7	8	11	13	10	9	10	13	7	8	9	8	7	8	7	5	6	7.8
15	5	5	6	6	5	6	5	5	7	6	7	10	11	11	4	2	3	8	8	9	12	12	13	12	7.4
16	12	12	11	12	11	9	8	11	12	11	12	11	15	16	16	12	8	8	5	7	7	8	8	7	10.4
17	7	12	13	14	16	13	15	12	16	17	18	18	15	12	11	10	8	7	6	6	5	6	5	8	11.2
18	9	11	14	14	18	16	19	19	19	20	21	21	21	20	19	18	15	13	12	12	11	11	7	9	15.4
19	9	5	9	8	7	9	9	10	10	13	13	13	12	12	11	11	11	8	8	5	6	6	5	4	8.9
20	5	4	5	4	4	6	5	6	5	6	8	8	11	13	11	10	8	7	6	3	4	1	3	3	6.1
HOURLY PRESSURE, 29 INCHES PLUS																									
13	0.81	0.80	0.79	0.79	0.79	0.81	0.82	0.84	0.86	0.86	0.85	0.82	0.80	0.77	0.75	0.75	0.77	0.79	0.79	0.80	0.81	0.83	0.82	0.80	-----
14	.79	.78	.76	.76	.77	.79	.80	.81	.83	.83	.82	.81	.78	.75	.73	.73	.74	.75	.76	.77	.77	.77	.76	.76	-----
15	.74	.73	.73	.73	.74	.76	.77	.79	.81	.79	.76	.73	.71	.71	.71	.70	.71	.73	.73	.74	.75	.75	.74	.73	-----
16	.71	.70	.68	.69	.70	.71	.73	.74	.76	.76	.75	.72	.70	.68	.67	.67	.69	.70	.71	.74	.75	.75	.74	.73	-----
17	.71	.69	.68	.68	.70	.71	.74	.77	.78	.79	.78	.76	.74	.71	.70	.71	.73	.74	.76	.78	.79	.79	.79	.78	-----
18	.77	.76	.76	.75	.75	.79	.81	.83	.85	.83	.81	.80	.77	.74	.72	.72	.74	.76	.78	.80	.81	.81	.82	.81	-----
19	.80	.79	.78	.77	.78	.79	.80	.82	.83	.84	.83	.80	.78	.75	.74	.72	.72	.72	.75	.77	.80	.82	.83	.82	-----
20	.81	.79	.78	.76	.77	.79	.81	.82	.84	.85	.83	.81	.78	.75	.72	.70	.72	.76	.70	.78	.80	.82	.82	.81	-----

TABLE 2.—*Balboa Heights, Canal Zone, October, 1926, hourly wind direction and velocity; hourly pressure*

Date	A. M.												P. M.												Mean
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid't	
HOURLY WIND DIRECTION																									
13	nw.	nw.	nw.	nw.	ne.	ne.	ne.	ne.	ne.	ne.	e.	se.	s.	s.	nw.	nw.	nw.	nw.	nw.	nw.	n.	ne.	ne.	ne.	
14	ne.	ne.	ne.	ne.	ne.	n.	n.	n.	n.	n.	ne.	ne.	se.	se.	s.	sw	se.	s.	s.	sw.	s.	sw.	s.	s.	
15	s.	s.	sw.	w.	sw.	sw.	sw.	sw.	s.	sw.	sw.	s.	s.	s.	s.	sw.	s.	s.	s.	s.	s.	s.	s.	s.	
16	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	sw.	s.	s.	s.	s.	s.	
17	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	
18	s.	s.	s.	s.	s.	se.	s.	s.	s.	se.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	
19	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	se.	se.	s.	se.	se.	se.	se.	se.	ne.	ne.	
20	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	se.	se.	se.	se.	se.	se.	se.	se.	se.	ne.	ne.	nw.	nw.	
HOURLY WIND VELOCITY, M. P. H.																									
13	2	2	3	4	2	6	4	6	7	5	5	5	7	9	3	3	2	3	2	2	4	7	6	3	4.3
14	6	6	7	4	3	2	3	2	1	3	5	5	5	8	8	2	4	7	6	14	9	8	17	20	6.5
15	12	12	6	2	5	3	1	1	14	22	24	21	25	26	25	23	19	18	17	14	16	15	23	23	15.3
16	22	21	21	22	18	18	22	23	27	28	23	20	21	24	21	19	22	17	16	18	14	19	19	22	20.7
17	21	19	19	28	28	24	26	23	27	29	24	23	24	24	22	26	17	11	11	6	9	14	14	17	20.2
18	14	10	12	12	11	9	13	16	18	18	18	18	19	17	17	14	13	15	10	9	10	10	11	11	13.5
19	14	16	10	10	14	12	11	11	18	17	17	14	18	14	11	7	8	7	6	6	4	5	5	10	11.0
20	9	6	9	10	9	6	4	6	5	6	5	8	7	6	5	6	4	5	5	2	6	9	2	1	5.9
HOURLY PRESSURE, 29 INCHES PLUS																									
13	0.82	0.80	0.79	0.80	0.79	0.81	0.84	0.86	0.87	0.87	0.84	0.82	0.80	0.78	0.76	0.76	0.76	0.78	0.80	0.80	0.81	0.83	0.82	.81	
14	.79	.78	.77	.77	.78	.80	.81	.82	.84	.85	.83	.82	.78	.76	.75	.75	.76	.75	.76	.78	.79	.78	.77	.76	
15	.75	.73	.73	.73	.73	.75	.78	.80	.82	.81	.80	.78	.75	.74	.73	.74	.75	.76	.77	.78	.80	.80	.79	.77	
16	.75	.74	.73	.74	.75	.76	.77	.77	.80	.80	.78	.77	.74	.72	.71	.70	.72	.73	.74	.75	.77	.78	.77	.75	
17	.73	.71	.70	.70	.73	.75	.78	.78	.80	.82	.81	.80	.77	.75	.73	.72	.75	.75	.77	.80	.81	.81	.81	.81	
18	.80	.78	.77	.76	.76	.80	.82	.84	.86	.86	.84	.81	.79	.77	.75	.75	.77	.78	.79	.81	.82	.83	.84	.83	
19	.82	.81	.81	.80	.80	.81	.83	.84	.86	.85	.83	.81	.79	.76	.75	.74	.74	.74	.76	.78	.81	.81	.81	.81	
20	.79	.78	.75	.75	.77	.80	.81	.83	.85	.85	.82	.80	.77	.74	.72	.70	.71	.73	.76	.78	.82	.83	.83	.82	

TABLE 3.—*Wind direction and velocity at different levels, as shown by pilot balloon ascensions at the United States Naval Air Station, Coco Solo, Canal Zone, during formation of a tropical cyclone in the southwestern Caribbean Sea, October, 1926.*

Flight No. (1926)	349.	350.	351.	353.	354.	355.	356.	357.	358.	359.	360.
Date and hour	13th, 0630.	13th, 1500.	14th, 0630.	14th, 1500.	15th, 0630.	16th, 0630.	18th, 0630.	18th, 1500.	19th, 0630.	19th, 1500.	20th, 0630.
Surface wind, direction and velocity.	SE., 0.9.	WSW., 3.1.	SE., 2.2.	W., 3.6.	S., 1.8.	SE., 3.6.	SE., 8.9.	SE., 8.9.	ESE., 5.4	E., 5.4.	SE., 1.3.
Air temperature and humidity.	74°, 95 per cent.	84°, 84 per cent.	76°, 96 per cent.	81°, 87 per cent.	75°, 95 per cent.	75°, 95 per cent.	76°, 87 per cent.	85°, 73 per cent.	75°, 91 per cent.	88°, 67 per cent.	74°, 95 per cent.
Pressure	29.79.	29.76.	29.77.	29.72.	29.75.	29.70.	29.77.	29.72	29.79.	29.73.	29.82.
Upper clouds	1 CiS.	2 CiS.	6 CiS N.	3 CiS N.	2 CiS.	2 CiS NE.	5 CiS NE.	4 CiS NE.	8 CiS NW.	8 CiS NW.	5 CiS NW
Intermediate clouds	2 ACu.					2 ACu NE		2 ACu NE.			
Lower clouds	6 SCu W.	4-2 Cu-SCu SE.	3 SCu NW.	¾ Cu/SCu SW.	7 SCu SW	4 SCu SW	5 SCu S	2 Cu S	1 SCu.	1 Cu SE.	2 Cu NE.
Visibility	6.	6.	6.	7.	6.	6.	6	6.	6.	6.	6.
Sun	Obscured.	Bright.	Intermittent.	Obscured.	Faint.	Obscured.	Intermittent.	Bright.	Intermittent.	Bright.	Bright.
Disappearance due to	Haze.	Bursting.	Haze.	SCu clouds.	SCu clouds.	Haze.	SCu clouds.	Fading, CiS.	Fading, CiS.	Haze.	Bursting.

Altitude of balloon		Wind																					
Minute	Meters	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
1	216	sse.	5.0	wsw.	2.1	sse.	5.0	ssw.	4.8	s.	4.6	sse.	8.3	se.	13.0	se.	7.5	ese.	9.7	ese.	8.0	ese.	4.7
2	414	ssw.	5.0	ssw.	2.5	s.	5.2	ssw.	4.0	ssw.	5.0	s.	10.6	sse.	15.8	se.	7.8	se.	11.6	ese.	8.3	ese.	3.6
3	612	sw.	4.5	sw.	3.8	wsw.	4.7	ssw.	4.2	sw.	5.8	s.	14.0	sse.	15.2	se.	8.9	se.	11.7	ese.	7.4	se.	2.8
4	801	wsw.	4.5	sw.	3.8	wsw.	3.1	ssw.	3.8	sw.	5.9	s.	13.3	sse.	14.3	sse.	10.5	se.	10.8	ese.	6.0	ese.	3.4
5	990	wsw.	4.5			wsw.	2.0			wsw.	5.8	s.	10.4	sse.	15.0	sse.	11.3	se.	10.3	se.	4.7	e.	3.8
6	1,170	w.	3.8			w.	1.6			wsw.	6.2	ssw.	10.2	sse.	16.6	sse.	10.8	se.	10.2	s.	3.0	ne.	3.4
7	1,350	w.	3.0			w.	1.4			wsw.	6.9	ssw.	11.0	s.	17.5	sse.	8.6	se.	9.5	s.	2.0	ne.	3.4
8	1,530	w.	2.9			nw.	1.2			sw.	7.6	ssw.	12.7			s.	6.4	se.	8.5	se.	1.0	ne.	3.7
9	1,710	w.	2.7			nnw.	1.3					sw.	14.3			s.	6.6	se.	8.3			ne.	3.0
10	1,890	wsw.	2.9			nw.	1.5															ne.	2.4
11	2,070	wsw.	2.5			nw.	2.0															nne.	3.7
12	2,250	ssw.	2.9			nnw.	2.9															nne.	5.7
13	2,430	s.	2.7			n.	3.4															nne.	6.3
14	2,610	sse.	2.5			n.	3.2															nne.	5.8
15	2,790	sse.	2.6			n.	3.0															nne.	6.0

Flight 352, made at 0745 on the 14th omitted.

TABLE 4.—*Weather conditions at Bluefields, Nicaragua, at a. m. and p. m. observations, October 12–18, 1926* (From Form 1001 A)

Day and hour	Barometer	Temperature	Wind direction	Velocity	Weather	Rainfall
	Inches	°		*M. p. h.*		*Inches*
12th, a.	29.88	75	w.	4	Cloudy	.57
12th, p.	29.88	80	0.	0	Partly cloudy	.00
13th, a.	29.88	76	nw.	2	Cloudy	.53
13th, p.	29.88	81	nw.	2	Partly cloudy	.05
14th, a.	29.86	76	w.	4	Cloudy	.12
14th, p.	29.83	78	nw.	2	do	.10
15th, a.	29.79	76	nw.	6	do	.61
15th, p.	29.88	76	w.	2	do	.15
16th, a.	29.70	75	w.	10	Rain	1.47
16th, p.	29.86	77	nw.	2	do	1.00
17th, a.	29.88	75	sw.	6	Cloudy	.00
17th, p.	29.77	82	sw.	4	do	.00
18th, a.	29.86	75	sw.	-------	do	.00
18th, p.	29.84	80	sw.	4	Rain	.07

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"SAN NICOLÁS"—THE TROPICAL STORM OF SEPTEMBER 10, 1931, IN PORTO RICO

By F. E. HARTWELL

[Weather Bureau, San Juan, P. R.]

According to the accustomed nomenclature of West Indian storms the one which raked the north coast of Porto Rico on the night of September 10 has been named "San Nicolás" from the saint's day of that date. The first intimation of abnormal weather previous to this storm was an almost perfect wide quadrant of wind directions extending from the Virgin Islands to Barbados on the morning of the 9th. The appearance at that time was that the area named was in the southwest periphery of a very wide cyclonic area. Broadcasts were immediately sent out in an endeavor to locate the center and bulletin issued from the San Juan office that morning was as follows:

> Advisory 9.00 a. m.—Sept. 10, 1931.—Disturbance of minor intensity has apparently passed through Leeward Islands and is approaching St. Thomas and St. Croix and will probably affect northeastern Porto Rico before midnight. No high winds have so far been reported and the lowest pressure is 29.72 inches at St. Martin. Caution advised small shipping on east coast of Porto Rico particularly.
>
> (Signed) HARTWELL.

Our special observers at St. Croix and St. Thomas sent the required messages and indications pointed to the path

FIGURE 1.—Distribution of rainfall in Porto Rico during hurricane of "San Nicolás," September 10–11, 1931. (Arrow shows path of center)

determine its intensity, but nothing of importance was received and by evening the low area had become elongated in a north-south direction, the southern extremity apparently filling up and the northern developing into a vortex of much narrower limits than at first indicated. Nothing below 29.72 inches (at St. Martin and Antigua) was reported, and no velocities above ordinary occurred within range of reporting stations. By the morning of the 10th the center had passed through the Leewards somewhere near St. Martin and was approaching the U. S. Virgin Islands of St. Thomas and St. Croix. The slightly north of the latter station, where by mid-afternoon the storm had developed to 60 miles per hour with northwest shifting to west winds and a low pressure of 29.57 inches. By the time it had reached San Juan the intensity had increased to a low pressure of 29.17 inches and an estimated wind velocity of 90 miles per hour. This estimate is based partially upon a stop watch record made by Pan-American Airways (Inc.) officials with their 4-cup Robinson anemometer at the air field and, of course, the total mileage and the dial readings of our own anemometer.

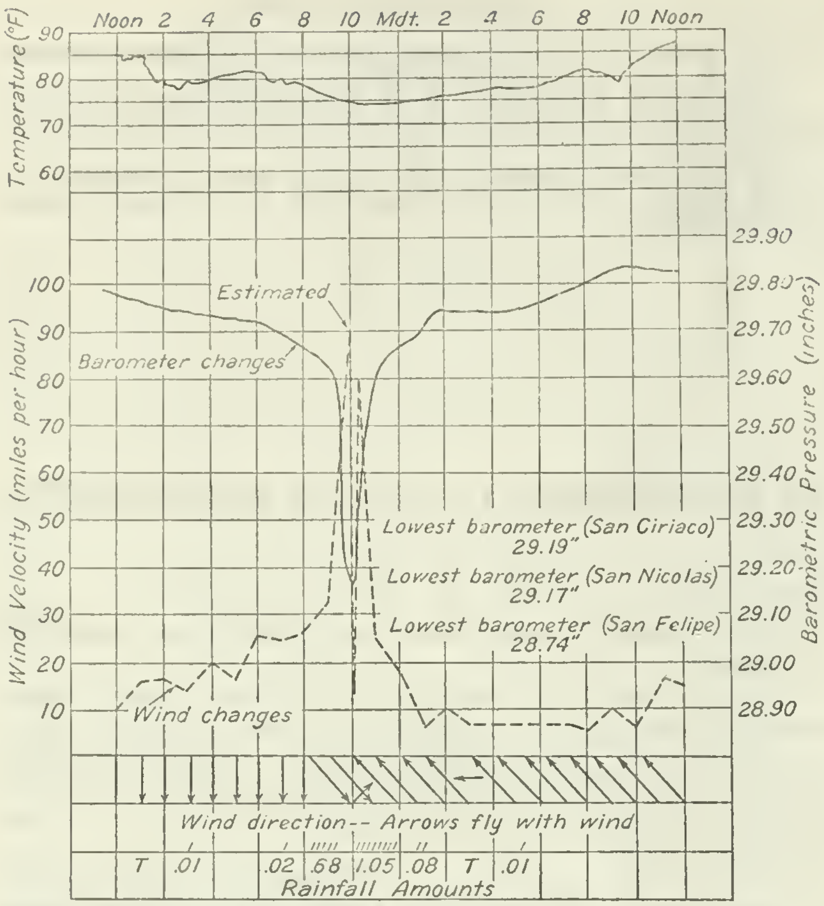

FIGURE 2.—Weather elements at San Juan, P. R., hurricane of September 10–11, 1931

So far the trajectory had been close to west-northwest and in this latitude, with the lowest pressures of the season between the Bahamas and Bermuda it seemed practically certain the storm would continue in that direction, affecting Porto Rico, probably with nothing more severe than heavy rain squalls. From St. Thomas, however, the track bent southward and from the afternoon of the 10th it pursued a due west course for many days, the center passing along the north coast of Porto Rico, with decreased intensity over Santo Domingo City, then again increasing throughout the remaining length of the Caribbean Sea. This trajectory is shown in the accompanying chart of storm tracks for this area this season.

In Porto Rico, while the information of Thursday evening was perhaps too sanguine, indicating that the center would probably pass as much a 50 miles north of San Juan, the warning of the morning had been well heeded and some preparation was effected where practicable. Two lives were lost and several minor injuries reported in San Juan. Much plate glass and light construction were destroyed, and some 50,000 boxes of fruit blown from the trees. The damage was confined to a strip of 5 or 6 miles in width extending from San Juan to Aguadilla, the damage varying considerably in this area with the character of the crops. The destructive portion of the storm was hardly more than 10 or 12 miles in diameter and the northern half of this was off shore. There was an interval of 15 minutes at San Juan which represented the center of the storm, but it is the opinion of the writer that the actual center passed a short distance north of San Juan as the first renewal of the wind was from the southwest, then after several minutes it became southeasterly. The wind during the first portion of the storm held northwest with practically no variation until the lull.

All electric service was broken and definite news of the passage of the center was sent out through the cooperation of the officials of the Spanish liner *Juan Sebastian Elcano* who communicated the dispatches to the main broadcasting station of the naval radio at Cayey, the local station of that service being badly crippeld by both wind and water and their usual land lines to Cayey being down.

A notable feature of the trajectory of all the storms this season has been their close adherence to an east-west course as indicated in the chart, whereas there is regularly a steady deviation toward the north almost from their inception with a recurve as soon as they reach latitudes 18° or 20°.

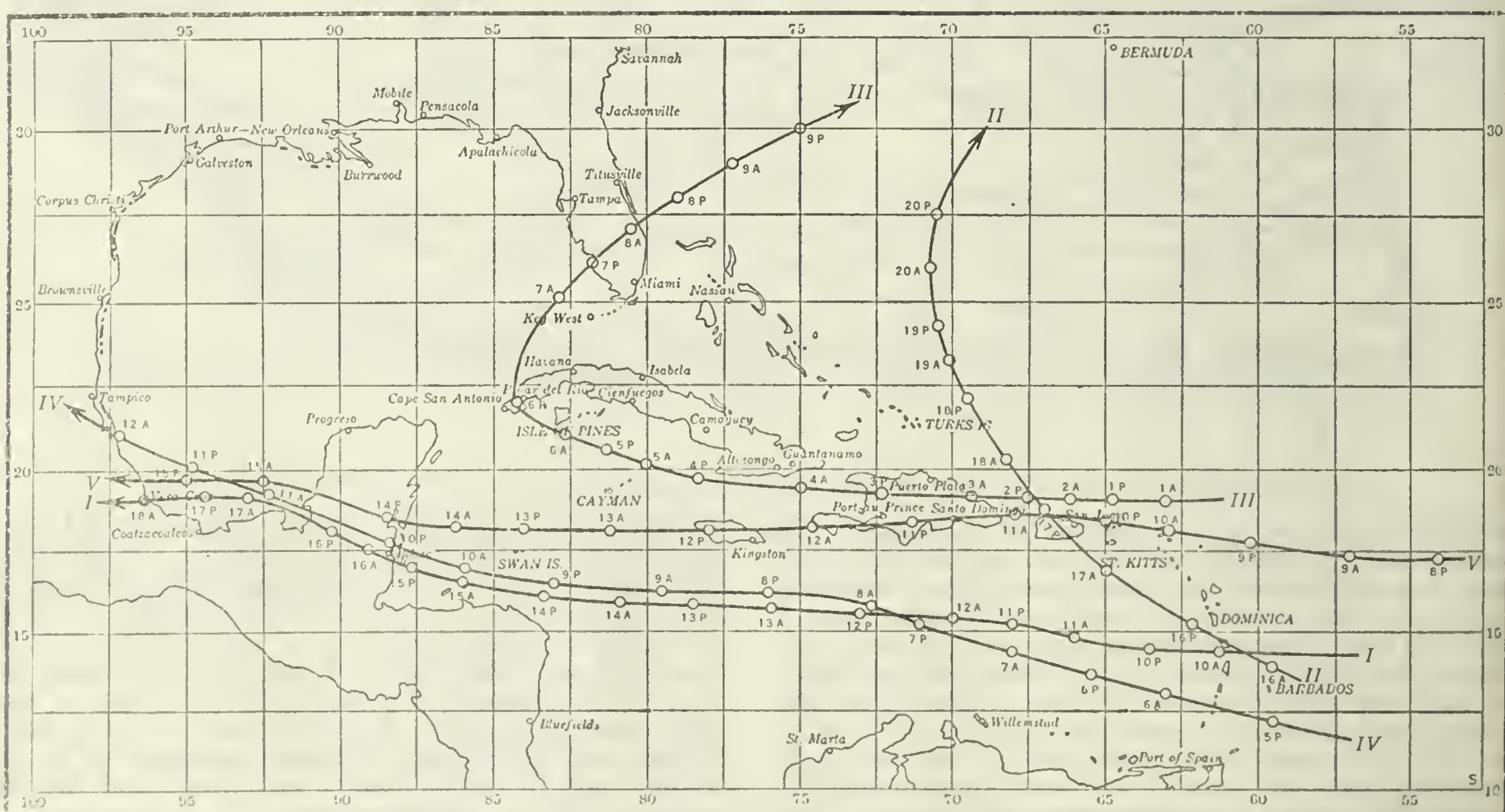

FIGURE 3.—Paths of hurricanes of 1931 (Plotted by Arthur J. Haldle): I, August 10–18 II, August 16–20; III, September 1–9; IV, September 5–12; V, September 8–15 ("San Nicolás")

INVESTIGATIONS OF THE DUST CONTENT OF THE ATMOSPHERE

By HERBERT H. KIMBALL and IRVING F. HAND

[Solar Radiation Investigations Section, U. S. Weather Bureau]

SYNOPSIS

This paper is a continuation of papers on the same subject that appeared in the MONTHLY WEATHER REVIEW for March, 1924, and June, 1925. It summarizes measurements of the dust content of the atmosphere made on the campus of the American University, District of Columbia, between December, 1922, and June, 1931, inclusive, excluding the month of June, 1923. This gives 9-year means for the winter and spring months and 8-year means for the summer and fall. The monthly averages and the annual totals show a gradual increase in the dust content of the atmosphere for the years 1923–1928, with a slight decrease in the years 1929 and 1930. Records of the total solar radiation received on a horizontal surface show that an increase in atmospheric dust has been accompanied by a decrease in the solar radiation intensity during the cold half of the year, November to April, inclusive, without a corresponding decrease during the warm months of the year. The greatest percentage of increase in the atmospheric dust content is shown in the minimum amount recorded in each month, where the annual average for 1930 was more than double that for 1923 and 1924.

This increase in local atmospheric dust does not appear to have been accompanied by a corresponding decrease in the distance to which prominent objects like mountain peaks and high hills can be seen.

A relation is shown between the sulphur (SO_2) content and the dust content of the atmosphere.

SUMMARY OF ATMOSPHERIC DUST MEASUREMENTS

The campus of the American University, District of Columbia, where atmospheric dust measurements have been made by the United States Weather Bureau since December, 1922, is in a sparsely settled suburb of Washington about 5½ miles northwest of the United States Capitol, 5 miles from all important railroads, and 2 miles northwest of the section known as Georgetown, of which that portion along the river front is largely given up to industry. The building of residences in this suburb is quite active, however, and the apartment-house section is much nearer, as well as more extensive, than it was in earlier years. Since apartment houses usually burn bituminous coal for heating, with inefficient stoking, it is not surprising that a summary of the atmospheric dust counts, given in Table 1, shows increased dustiness of the atmosphere, and especially during the cold half of the year, November to April. The years 1929, 1930, and 1931 have been an exception to this general rule, in so far as the monthly means and monthly maxima are concerned, but not in respect to the monthly minima. This is significant, as it indicates a permanent local pollution of the atmosphere that is gradually increasing in intensity. The recent decrease in the monthly means and monthly maxima may be attributable in part at least to the unusually warm winters of 1929-30 and 1930–31, and the resulting decrease in coal consumption.

TABLE 1.—*Dust content of the atmosphere at the American University, District of Columbia, at 8 a. m. (dust particles per cubic centimeter)*

MONTHLY MEANS

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual means
1922	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1, 228	-----
1923	1, 061	905	540	476	393	-----	397	388	386	395	451	557	540
1924	719	533	409	645	376	420	539	326	335	598	1, 110	1, 159	597
1925	723	1, 092	909	753	416	507	480	484	514	608	787	1, 444	726
1926	1, 631	1, 517	1, 370	755	573	578	542	532	565	692	851	1, 056	888
1927	1, 011	1, 116	939	721	729	607	933	760	859	1, 021	1, 097	1, 176	914
1928	1, 455	1, 450	1, 232	856	668	596	757	675	774	1, 082	979	1, 227	978
1929	1, 419	1, 086	652	610	621	469	549	626	638	616	858	881	752
1930	898	736	668	753	614	544	573	828	866	1, 020	995	875	781
1931	906	951	809	815	608	631	-----	-----	-----	-----	-----	-----	-----
Average	1, 091	1, 043	836	709	555	544	596	577	617	754	891	1, 047	772

TABLE 1.—*Dust content of the atmosphere at the American University, District of Columbia, at 8 a. m. (dust particles per cubic centimeter)*—Continued

MAXIMUM

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual means
1922	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2, 088	-----
1923	3, 680	2, 050	1, 155	1, 182	905	-----	793	794	812	853	1, 023	2, 340	1, 394
1924	2, 403	1, 964	1, 280	1, 661	1, 154	1, 250	1, 953	796	823	1, 366	1, 987	2, 551	1, 595
1925	1, 352	2, 370	2, 247	7, 077	781	991	1, 016	1, 037	1, 109	1, 432	1, 558	3, 106	2, 006
1926	3, 828	2, 995	2, 999	1, 527	1, 042	1, 035	985	941	1, 073	1, 426	3, 975	2, 388	2, 018
1927	3, 511	2, 474	1, 877	1, 558	1, 529	1, 560	1, 651	1, 443	1, 672	3, 133	2, 566	2, 984	2. 163
1928	3, 620	3, 557	2, 617	2, 039	1, 575	1, 434	1, 308	1, 302	1, 493	2, 772	2, 751	4, 116	2, 382
1929	3, 620	1, 982	1, 583	1, 153	1, 082	897	922	976	1, 010	1, 098	1, 628	1, 606	1, 463
1930	3, 780	1, 512	1, 176	1, 166	1, 701	855	1, 052	1, 323	1, 426	2, 066	1, 953	1, 779	1, 649
1931	1, 617	1, 649	1, 352	1, 434	846	1, 073	-----	-----	-----	-----	-----	-----	-----
Average	3, 046	2, 284	1, 810	2, 089	1, 179	1, 137	1, 210	1, 076	1, 177	1, 761	2, 180	2, 551	1, 792
Absolute maximum	3, 828	3, 557	2, 999	7, 077	1, 701	1, 560	1, 953	1, 443	1, 672	3, 133	3, 975	4, 116	-----

MINIMUM

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual means
1922	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	298	-----
1923	214	105	113	113	65	-----	90	110	59	96	71	90	108
1924	124	97	76	151	124	155	124	87	97	155	113	124	118
1925	57	77	87	202	149	197	132	143	118	130	124	344	147
1926	160	298	223	227	187	214	218	145	132	82	76	145	176
1927	155	185	145	138	225	122	288	187	218	99	172	143	173
1928	160	254	162	174	126	202	384	132	126	334	120	109	190
1929	160	200	101	242	134	128	170	191	176	124	323	204	179
1930	361	253	237	241	134	178	150	144	278	384	231	376	247
1931	372	369	174	233	275	216	-----	-----	-----	-----	-----	-----	-----
Average	196	204	146	191	158	176	194	142	150	176	154	204	174
Absolute minimum	57	77	76	113	65	122	90	87	59	82	71	90	-----

The dust counts have been made by Mr. Hand on all working days except on the few occasions when he was absent from the city and an observer was not available to take his place. An Owens jet dust counter has been used in collecting the dust and a microscope magnifying 1,000 diameters to determine the number of particles per unit of space. For a description of the Owens instrument see the earlier paper in the REVIEW for March, 1924.

THE RELATION BETWEEN ATMOSPHERIC DUSTINESS AND SOLAR RADIATION INTENSITY

From time to time short notes have appeared in the MONTHLY WEATHER REVIEW with reference to the diminution in solar radiation due to local smoke. (See the MONTHLY WEATHER REVIEW, October, 1924, vol. 52, p. 478, fig. 5; April, 1925, vol. 53, p. 147; January, 1926, vol. 54, p. 19; and January, 1929, vol. 57, p. 18.) Table 2 shows a general depletion at the American University, District of Columbia, in the annual totals of solar radiation for 1923–1928, and in the monthly averages during the cold part of the year for the period 1923–1930. The monthly averages for the warm part of the year show little departure from normal values. The depletion in solar radiation intensity is what would be expected from the increase in atmospheric dustiness shown in Table 1.

A similar decrease in solar radiation intensity recorded at Madison, Wis., is attributed by the official in charge of that station to increased smokiness of the atmosphere due to a marked increase in the population of the section of the city in which the Weather Bureau office is located. (See the MONTHLY WEATHER REVIEW, 1931, vol. 59, p. 272.)

TABLE 2.—*Departures of monthly totals of solar radiation received on a horizontal surface at Washington, D. C., from monthly normal values for the period 1914–1931 (gram-calories per cm.²)*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1923	−1,145	−859	−645	−419	+646	+311	+58	−1,179	−1,086	−73	−648	−248	−5,278
1924	+286	+289	+160	+675	−766	−1,867	+1,590	+740	−1,355	+1,549	−467	−640	−6
1925	−413	−721	+35	+98	+966	+979	+35	+1,176	−574	−2,373	−175	+28	−959
1926	−14	−1,176	+1,099	+784	+2,072	−1,071	−847	−2,919	−1,827	−959	−700	−917	−6,475
1927	−686	−1,001	−2,079	−1,064	−2,772	−105	+77	−1,260	+406	+452	−690	+307	−8,415
1928	+112	+77	+245	−1,050	+56	−972	+1,764	−1,032	−1,701	+672	+364	−245	−1,740
1929	−217	+1,162	−854	−1,288	+532	+1,274	+2,541	+2,002	+637	+511	−308	−219	+5,773
1930	−742	+119	+413	−161	+2,443	+777	−1,216	+3,045	+1,281	+2,681	−455	+222	+8,405
Means	−352	−273	−203	−303	+397	−84	+500	+72	−527	+308	−382	−214	−1,087
Departures	−8%	−4%	−2%	−3%	←			+0.1%		→	−6%	−5%	---------

ATMOSPHERIC DUST AND VISIBILITY

In the paper of June, 1925, already referred to, it was shown that the product

$$D \times N \times R.\ H.$$

approximates to a constant, C, where
D = distance in miles to the most distant object that can be seen, N[1] = the number of dust particles per cubic centimeter, and $R.\ H.$ = the relative humidity expressed as a percentage.

A recomputation of the data there given for $D=10$ miles or more, and applying weights corresponding to the number of observations, gives 444,000 for the value of C.

A summary of dust and visibility measurements made between May, 1925, and June, 1931, inclusive, and given in Table 3, gives for the weighted mean value of C corresponding to visibilities in excess of 25 miles, 432,000, or approximately the value found from earlier observations. For shorter distances of visibility C has increased in value by from 50 to 100 per cent.

This is interpreted to mean that the local dust cloud has so little extent that it does not materially interfere with the visibility of prominent objects at moderate distances, while the most distant objects still require the most favorable conditions to be distinguished.

TABLE 3.—*Relation between atmospheric dustiness and visibility of distant objects*

SUMMER					WINTER				
Number of observations	N=dust particles per cubic centimeter	$R.\ H.$, per cent	D=visibility, miles	$C=D\times N\times R.\ H.$	Number of observations	N=dust particles per cubic centimeter	$R.\ H.$, per cent	D=visibility, miles	$C=D\times N\times R.\ H.$
35	155	62	40.4	388,000	19	158	62	33.3	331,000
103	253	69	27.5	480,000	15	250	54	34.7	468,000
114	353	65	24.2	555,000	34	198	59	33.9	366,000
123	445	70	20.1	626,000	21	362	64	25.4	588,000
100	556	68	20.7	783,000	28	448	66	24.8	733,000
119	647	70	16.0	725,000	35	553	65	21.0	755,000
95	751	75	15.8	847,000	49	652	69	20.0	900,000
118	851	72	12.1	741,000	26	751	67	18.4	926,000
69	943	72	11.8	801,000	48	857	60	16.0	823,000
91	1,075	73	9.2	788,000	35	943	67	13.3	840,000
62	1,311	77	7.5	757,000	58	1,091	70	10.1	771,000
33	1,641	74	5.4	656,000	54	1,341	74	8.9	883,000
6	2,636	79	8.0	1,666,000	56	1,704	71	6.6	799,000
					38	2,446	75	3.8	703,000
					9	3,595	85	2.1	642,000

A copy of the dust counts made at the American University, District of Columbia, is mailed each month to Dr. J. S. Owens, London, England, superintendent of observations, investigations of atmospheric pollution, department of scientific and industrial research. In a letter received after this paper was completed Doctor Owens transmits the following results of his study of the observations for the year April, 1930–March, 1931. The equation that he developed seems to give with considerable accuracy the relation between N, $R.\ H$, and V ($V=D$ of this paper). He says:

Visibility and wind velocity are given in the returns sent in, and an attempt has been made by examining the whole of the figures for the year to find some relation between visibility, number of suspended particles, and relative humidity. The result obtained is indicated in the curve (fig. 1) given below:

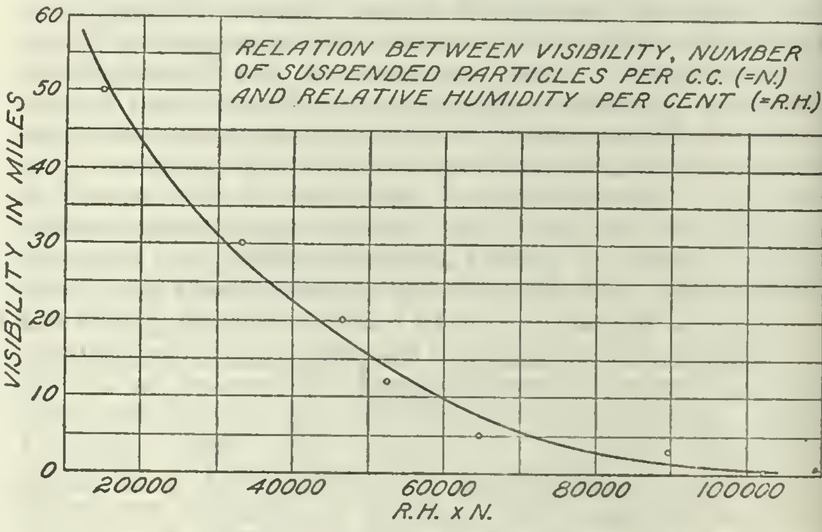

FIGURE 1.—Relation between visibility, V; number of suspended particles, N; and relative humidity, $R.\ H.$

This was the result of many trials of different combinations between number of particles and relative humidity. To get consistency in the results, it is evident that some provision should be made to eliminate the effect of varying wind direction. The dust counts were made at one particular point, whereas visibility was governed by the conditions as to dust, etc., at other places along the line of view. It is evident therefore that the wind direction might make a great difference in the apparent relation between visibility, so measured, and dust contents. To eliminate this, only the days with a north wind were taken and other days neglected. The visibility, relative humidity and number of dust particles were tabulated and averages obtained of the relative humidity and dust counts for the different visibility distances. The curve given (fig. 1) is for visibility plotted against the product of relative humidity and the number of dust particles.

The wind velocity is not taken into account in this curve because it appeared reasonable to assume that it was one of the factors governing the number of particles and was therefore already taken account of in the figure for the number of particles per cubic centimeter. The curve is remarkably smooth and agrees well with the equation

$$V=340-69 \log (RH \times N)$$

where V= visibility in miles, RH= relative humidity, and N= number of particles per cubic centimeter.

[1] This N must not be confused with N=the number of nuclei of condensation found by the use of the Aitken dust counter.

This is not quite the same as the equation evolved by Doctor Kimball (see the REVIEW for June, 1925, 53:243), in which he gives the visibility in terms of the relative humidity and number of particles as—

$$V=\frac{390,000}{RH\times N}\quad\text{(approx.)}$$

It seems probable that any expression for visibility of this form would break down when approaching the point of saturation of the air, as in this neighborhood, apart from the effect of special pollution by hygroscopic salts, we might expect a rather sudden loss of visibility rather than a gradual one.

Since to obtain this curve (fig. 1) only days with a north wind were taken, it is not to be expected that the equation will apply when the wind is not north. Indeed, we can not hope for any general expression relating to dust count, relative humidity, and visibility until and unless we know the conditions along the line of vision. It would appear, however, that, knowing these conditions, there is good ground for believing that a simple relation might be established.

MEASUREMENTS OF THE SULPHUR (SO_2) CONTENT OF THE ATMOSPHERE

Method of measurement.—Equal quantities of a solution of distilled water, iodine, potassium iodide, and soluble starch were placed in two 20-liter bottles, each bottle being tightly sealed but provided with a ground-glass stopcock. The pressure within one bottle was reduced to one-half of the current atmospheric pressure, the stopcock closed, and the bottle was then shaken vigorously in order to have the liquid wash around the entire interior glass surface, and then the stopcock opened, the bottle being vigorously shaken until normal atmospheric pressure was resumed inside of it. The liquid in the comparison bottle was also similarly shaken, but the air was not disturbed within this bottle, a detail merely to approximate similar conditions in the two bottles.

The liquids in the two bottles were than placed in titration bottles; and if the tint of blue in each bottle was the same, no indication of the presence of sulphur evidenced itself. If, however, the tints differed, simple titration methods with the use of potassium iodide and other simple chemicals were resorted to in order to bring them to the same tint of blue.

TABLE 4.—*Dust particles per cubic centimeter and volumetric sulphur content of the atmosphere in parts per million*

Day of month	1926				1927							
	November		December		January		February		March		April	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
1	718	0	1,046	0.20			1,667	0.30	1,436	0.10	145	0.10
2	519	T.	145	0			519	T.	1,044	T.	260	0.15
3	1,529	0.20	1,756	0.85	1,730	0.40	1,000	0.10	166	0		
4	853	0.05	1,558	0.50	676	0.15	1,243	0.25	187	T.	781	T.
5	781	0.40			897	0.25	239	T.	1,027	0.20	607	0.45
6	1,044	0.90	676	0	729	0.10					1,193	0.20
7			918	0.35	859	0	1,462	0.15	1,147	0.30	155	0
8	250	0.35	1,126	0.20	781	0.25	[1] 1,831	0.20	414	0	498	0.10
9	225	0.40	1,453	0.10			1,777	0.40	1,625	0.40	149	T.
10	76	0	901	0.35	895	0.60	2,474	0.65	1,201	0.55		

[1] Additional data for Feb. 8:

Time	Dust, particles per cubic centimeter	Sulphur, parts per million
10 a. m.	2,470	0.95
11 a. m.	2,066	0.45
Noon	790	0.10
1 p. m.	607	T.
2 p. m.	680	0.25
3 p. m.	1,216	0.40

TABLE 4.—*Dust particles per cubic centimeter and volumetric sulphur content of the atmosphere in parts per million*—Continued

Day of month	1926				1927							
	November		December		January		February		March		April	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
11	365	0.10	498	0.20	584	0.35	1,426	T.	1.877	0.70	991	0
12	779	0.10			1,243	0.70	2,234	0.50	376	0.39	353	0.10
13	1,256	0.75	1,457	0.10	603	0.85					1,457	0.25
14			781	0.25	187	0.10	223	T.	145	0	571	T.
15	288	0.15	1,111	0.15	785	0	834	0.25	972	0.20	983	0.10
16	90	0	727	0			1,348	0.40	1,256	0.30	498	T.
17	844	0.10	1,653	0.35	985	0.20	197	T.	1,672	0.85		
18	781	0.60	521	0	3,072	1.60	376	0.10	498	T.	1,046	0.15
19	1,004	0.35			1,359	0.45	523	0.20	1,130	0	1,529	0.30
20	1,518	0.55	2,024	0.45	607	0.60					729	0.10
21			[2] 2,388	0.70	361	0.40	1,676	T.	823	0.35	225	0
22	781	0.40	344	1.25	155	0.15			622	0.40	166	0
23	916	0.65	834	0.75			1,151	0.20	1,310	0.15	386	T.
24	1,646	2.65	1,546		773	0.65	365	0.10	586	T.		
25					1,947	0.50	1,567	0.75	1,182	0.10	580	0
26	[3] 3,975	3.10			651	0.10	185	0	922	T.	970	0.10
27	143	T.	1,319	0.80	260	0					1,457	0.25
28			309	0	3,511	0.45	1,348	T.	676	0.15	130	0
29	521	0.40	628	0.20	1,044	0.15			918	0	1,319	0.10
30	370	0.10	386	0.45					1,252	0.20	1,558	0.15
31			1,359	0.65	586	T.			886	0.10		

Day of month	1927											
	May		June		July		August		September		October	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
1			475	0	464	0	1,443	T.	1,424	0.05	796	0
2	229	0.05	897	0	918	0	300	0	813	T.		
3	674	0.15	678	0			1,044	T.			1,210	0.05
4	596	0.20	1,436	0			1,098	T.			99	0
5	622	0			1,006	0.20	918	0			680	T.
6	1,516	T.	149	0	624	0	622	0	374	0	1,252	0.10
7	899	0.10	674	0.15	1,204	T.			970	0	970	0.05
8			307	0	806	T.	1,239	0	1,651	0	307	T.
9	271	0.20	603	0	834	0	674	0	288	0.05		
10	727	0	865	T.			288	0	708	0	1,193	0.15
11	603	0	1,147	T.	731	0	708	0			1,525	0.20
12	806	0.10			1,128	0	1,004	0.05	374	0	918	0.10
13	246	0	143	0	922	T.	1,233	T.	1,042	0	225	0
14	353	0	603	0.05	353	0.10			1,518	0.05	813	T.
15			729	T.	1,457	0	225	0	983	T.	[4] 3,133	2.40
16	225	0	164	T.	288	T.	781	0	781	T.		
17	269	0	813	0.20			1,233	0	1,193	0.10	1,646	0.25
18	1,529	0	888	0	1,037	0	187	0			286	0
19	1,252	0			918	T.	225	0	407	0	162	0
20	422	0	[5] 271	0.15	785	0.10	1,004	T.	353	0	307	0
21	1,466	0.10	832	T.	1,006	0			416	0	363	0
22			256	0.20	1,338	0.15	1,214	0.05	218	0	790	0
23	1,138	0	584	0	601	0.10	229	0	496	0		
24	496	0	1,560	T.			435	0	1,214	T.	1,518	0.35
25	928	0.15	441	T.	1,006	T.	225	0			1,042	T.
26	458	0			1,046	0	804	T.	1,518	0.05	601	0.15
27	386	0	122	0	781	0	1,252	0	1,672	0.05	1,552	0.20
28	624	0	363	0	1,426	0.05			790	0.10	1,346	0.15
29			218	0	993	T.	498	0	813	0.05	1,840	0.25
30			554	T.	1,651	0.10	645	0	601	0		
31	1,483	0.15					991	0			1,976	0.15

Day of month	1927				1928							
	November		December		January		February		March		April	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
1	1,000	T.	496	0			1,784	0.20	1,443	0.10		
2			970	T.			729	0	680	0	1,155	0
3	435	0.10	269	0	1,672	0.20	2,070	0.25	943	0.10	966	0
4	601	0			825	T.	1,768	0.20			2,039	0
5	905	0	166	0	1,000	T.			441	0	695	0.40
6			393	T.	1,243	0.05	1,042	0.10	2,617	0.55	907	0
7	1,105	0.10	1,436	0.25	1,651	0.10	3,511	0.90	2,188	0.40	699	0
8	1,661	0.40	676	T.			970	0	1.672	0.20		
9	1,911	0.10	363	0.05	1,730	0.20	813	0	2,020	0.95	878	0
10	2,566	0.55	836	0.25	2,184	0.45	1,453	0.15	622	0.10	645	0
11	1,621	0.20			689	0.10	622	0			475	0.20
12	603	0	1,394	0.20	985	T.			2.190	0.80	252	0.30
13			2,043	0.35	2,961	0.50	2,358	0.35	1,831	0.65	177	0

[2] Dense smoke cloud enveloped university this date; 4,502 particles of dust per cubic centimeter at 1·30 p. m.

[3] Much soot.

[4] Haze in west; local smoke with noticeable sulphur odor.

[5] Spores.

TABLE 4.—*Dust particles per cubic centimeter and volumetric sulphur content of the atmosphere in parts per million*—Continued

Day of month	1927				1928							
	November		December		January		February		March		April	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
14	1,182	0.10	145	0	1,558	0.10	2,066	0.20	2,386	1.30	178	0
15	884	T.	1,831	0.40	------	------	254	0	405	0	------	------
16	2,512	0.45	2,598	1.10	2,297	0.55	1,665	1.10	2,402	0.35	418	0
17	1,420	0.20	143	0	1,042	0.20	1,348	0.25	1,764	0.20	1,533	0
18	359	0	------	------	1,667	0.40	727	0.80	------	------	456	0.25
19	172	0	496	T.	2,176	0	------	------	164	0	1,321	0
20	------	------	796	0.45	313	0	1,651	0.10	557	0	1.533	0.10
21	970	0	1,651	0	729	0	1,350	0.20	953	0.20	2,039	T.
22	783	0	521	0.35	------	------	983	0.30	689	T.	------	------
23	1,203	0	1,453	0.20	943	0	1,825	0.10	556	0	1,113	0.45
24	------	------	------	------	2,251	0.20	689	0	882	0	867	0.40
25	811	0	------	------	160	0	1,432	0.20	------	------	174	0
26	1,940	0	------	------	1,539	0.10	------	------	1,853	0.10	672	0
27	------	------	2,253	0.15	899	0.10	832	0	376	0	894	0
28	374	0	2,795	0.60	183	0	804	0.25	1,764	0.20	252	0.20
29	916	0	1,037	0.20	------	------	3,557	1.20	1,809	0.10	------	------
30	403	0.10	1,646	0.30	3,620	0.65	------	------	170	0	1,073	0
31	------	------	2,984	0.50	2,050	0.15	------	------	162	0	------	------

Day of month	1928											
	May		June		July		August		September		October	
	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur	Dust	Sulphur
1	966	0	569	0	------	------	628	0	------	------	334	0.20
2	490	0	964	0.20	384	0	655	0	------	------	1,485	1.15
3	981	0	------	------	865	0	196	0	------	------	1,401	0.25
4	1,163	T.	------	------	------	------	403	0	------	------	655	0.40
5	1,575	0	376	0.10	1,107	0.25	------	------	------	------	672	0.20
6	------	------	275	0	420	0	563	0	437	0	796	0.45
7	811	0	914	0.10	------	------	846	0.15	731	0	------	------
8	315	0	1,434	0.25	------	------	1,151	0.20	632	0.15	1,308	0.65
9	126	0.10	594	0	------	------	571	0.30	------	------	1,401	0.30
10	336	T.	------	------	------	------	790	0	1,493	0.25	687	T.
11	934	0	1,132	T.	------	------	359	0.45	286	0	1,258	1.60
12	134	0	286	0.15	1,308	0.20	------	------	571	0.20	830	0.40
13	------	------	605	0.25	1,014	0.10	132	0	1,092	0.30	1,199	0.55
14	821	0	202	0	386	0.30	527	0	302	0	------	------
15	351	0	655	0	------	------	586	0	832	0.10	2,163	1.50
16	494	0.10	722	0	586	0	701	0.10	------	------	1,596	1.10
17	1,006	0.25	------	------	628	0	773	0	1,294	0.40	2,772	1.75
18	216	0.35	788	0	386	0	655	0	1,159	0.30	1,888	0.65
19	502	0.20	336	0.10	821	0	------	------	361	0	788	T.
20	------	------	907	0.20	947	0	1,117	0.25	126	0	351	0
21	620	T.	202	0.10	672	0.10	1,302	0.35	------	------	------	------
22	603	0	410	0	------	------	437	0	------	------	998	0.20
23	1,210	0.25	426	0.15	727	0.10	672	0	------	------	1,258	0.45
24	294	0	------	------	865	0	899	0.10	861	0.25	739	T.
25	403	0.35	206	0	722	0	662	0	1,064	0.35	840	0.25
26	235	0.10	972	0.15	1,049	0	------	------	880	0.30	393	0.20
27	------	------	594	0	714	0	907	0.25	1,453	0.90	628	0.35
28	1,006	0.25	588	0	861	0	594	0.30	586	0.20	------	------
29	888	0.10	458	0.05	------	------	351	0	538	0.55	697	0.60
30	------	------	284	0	470	0	626	0	------	------	872	0.55
31	437	0	------	------	[6] 972	1.20	1,109	0.40	------	------	1,210	0.75

[6] Haze.

Table 4 gives the daily sulphur measurements, together with the determination of the dust content of the atmosphere. The two measurements were made at the same place and the sulphur determinations followed immediately the dust measurements.

Table 5 summarizes the atmospheric sulphur determinations. From May to August, inclusive, on at least half the days on which determinations were made, not a trace of sulphur was found, and from April to September, inclusive, on more than half the days the amount present was not measurable (T. or 0). Also, from April to August, inclusive, the measured amount did not exceed in volume 0.45 parts per million, and in the majority of cases it did not exceed 0.2.

An amount in excess of one part per million in volume was measured on only 15 days out of the 600 on which measurements were made. Five of these days were in October, 1928, and were accompanied by an unusual number of dust particles, which quite probably came from a furnace that was being operated by the nitrate fixation laboratory on the American University campus to reduce certain rock material for the purpose of extracting phosphoric acid and potash. Eight of the remaining ten days with much sulphur were also days with many dust particles, the maximum of sulphur, 3.1 parts per million, on November 26, 1926, having as its accompaniment 3,975 dust particles per cubic centimeter. October 15, 1927, with 2.4 parts of sulphur per million had 3,133 dust particles per cubic centimeter, and there was a noticeable odor of sulphur from local smoke. December 22, 1926, with 1.25 parts of sulphur per million had only 344 dust particles per cubic centimeter, but it was raining at the time, and this would have a tendency to precipitate local dust from the lower atmospheric layers. On July 31, 1928, with 1.2 parts of sulphur per million, only 972 dust particles per cubic centimeter were collected by the Owens jct dust counter, but a note states that there was a dense haze, with the wind from the south. Such a wind would bring smoke from the industrial section of Georgetown.

The chemical process used in measuring atmospheric sulphur records in units of 1 part in 20,000,000 by volume, while it is generally conceded that 2 parts in a million is noticeable by its sulphur odor to the average individual.

TABLE 5.—*Summary of atmospheric sulphur determinations*

Parts per million	Average monthly occurrences											
	November	December	January	February	March	April	May	June	July	August	September	October
0	7.5	5.5	4.5	4.0	7.5	11.0	14.0	12.5	12.5	17.5	9.0	4.5
T.	2.0	2.0	2.0	3.5	3.0	3.0	2.0	4.5	3.5	3.0	2.0	3.5
0.05 to 0.20	7.0	6.0	9.0	8.0	8.5	7.0	7.0	7.5	5.5	3.0	6.0	7.0
0.25 to 0.45	4.0	6.5	4.5	5.0	4.0	4.5	2.5	1.0	1.0	3.5	3.5	5.5
0.50 to 0.95	3.0	4.0	4.5	2.5	3.5	0	0	0	0	0	1.0	3.0
1.00 or more	1.0	1.0	0.5	1.0	0.5	0	0	0	0.5	0	0	3.0
Average number of days	24.5	25.0	25.0	24.0	27.0	25.5	25.5	25.5	23.0	27.0	21.5	26.5

These sulphur determinations were made at the request of the United States Bureau of Standards. They constitute a link in a series of tests made in cooperation with the International Nickel Co. in a study of the durability of wire screens under different conditions. Measurements made in Pittsburgh represented conditions in an industrial city. Measurements at the navy yard, Portsmouth, Va., represented seacoast conditions, where the atmosphere contains many salt crystals. The campus of the American University, District of Columbia, was expected to approximate open-country conditions.

VIOLENT LOCAL STORM IN NEVADA, JULY 24, 1931

By J. R. Fulks

[Weather Bureau Office, Winnemucca, Nev., August 10, 1931]

An intense storm, resembling a small tornado, occurred at the Leonard Creek ranch, Humboldt County, Nev., at about 1 p. m. (one hundred and twentieth meridian time) on July 24, 1931. This ranch is about 70 miles northwest of Winnemucca and at about 118° 47′ W., 41° 30′ N.

The scene of the storm was visited two days later by Mr. Smith, official in charge at Winnemucca, and myself.

The Leonard Creek ranch is located in a narrow canyon which opens into the northern edge of the Black Rock Desert, a level arid region about 60 miles long and 15 to 20 miles wide. The country immediately surrounding the ranch is mostly low hills with rather high mountains rising a few miles to the north.

This storm appeared to have a whirling motion, as described by Mr. Ramon Montero, one of the ranch owners, and was of considerable violence along a short and very narrow path.

The storm, while of little significance when compared to local storms, occurring in the middle western and southern portions of the United States, deserves mention because of the infrequency of such in this vicinity, and also because it occurred on the same day as a thunderstorm, which, as observed at Winnemucca, showed cold-front characteristics. It is also worthy of mention that it happened during the period of warmest weather of record in the middle Plateau region.

We are able to find a record of only two tornadoes (or those so classified) in Nevada hitherto. One of these was at Winnemucca on December 16, 1879, the other at Fallon on April 29, 1915.

Mr. Montero describes the whirl as originating on or near a small conical peak about 500 yards west of the ranch buildings. Its development is given as accompanied by a single dark cloud and a few claps of thunder; the general appearance of the sky as clear except for a few other scattered clouds and a thunderstorm which appeared to be passing over the mountains to the north. Temperature is described as being excessively warm before, and slightly cooler after, the storm; and wind, both before and after, as very light. A better description of the appearance could not be obtained, as Mr. Montero explained that the excitement incident to getting himself and family to a place of safety made a more accurate observation impossible.

The whirl apparently moved in a curved or irregular path, as the only building destroyed is east of the place where it was first observed, and at the point of damage the storm moved toward the northeast. The exact place at which it dissipated could not be determined, but débris is scattered for only about one hundred yards, and no evidence of it is visible further than that. Land in that direction is covered with sagebrush. The total distance traversed was, therefore, as near as could be determined, about 600 yards. Its width is estimated at 50 feet.

A small narrow lambing shed about 50 feet long, substantially constructed of heavy timber, was completely destroyed. A larger building adjoining it to the west and apparently no more substantial was not damaged. A garden is to the east of the shed, and while Mr. Montero says some of the vegetables were uprooted, but little damage was apparent. Timber of the building, broken down but still hanging, leaned toward the north. A small schoolhouse about 75 feet to the north, located within the edge of a grove of trees, was not damaged. A hay wagon, standing between the two buildings and about 25 feet from the schoolhouse, was moved eastward a distance of 200 feet, where it was left undamaged. Mr. Montero believes that this was picked up completely from the ground. No evidence of its being moved along the surface could be found except within a few feet of the place it was left after the storm. Had it moved over the surface, the tongue, which hung loose, should have left a visible mark. Very little damage was done to the grove of trees; a few broken branches left hanging were twisted at the point broken, and some débris was caught in the trees.

No data were obtainable on the rate of movement, except that Mr. Montero says it seemed to come up and was over in an instant. Also the direction of whirl could not be determined.

Mr. Montero estimated damage to the building at $1,500. No one was injured.

The weather map on the morning of July 24 shows a trough of low pressure over California and Arizona, axis northwest and southeast, and a ridge of high pressure extending southeastward from the mouth of the Columbia River into northern Nevada. The following morning shows the trough less marked, and pressure gradients over the remainder of the country very weak, with the ridge of high pressure in the Northwest no longer noticeable. Very light precipitation occurred during the 24 hours over a narrow strip extending from northern Nevada to southeastern Wyoming.

A thunderstorm began at Winnemucca at 6.46 p. m. of the 24th; rain began at 6.50 p. m. and ended at 9.15 p. m., with total precipitation 0.12 inch. Wind from 2 p. m. to 7 p. m. was from the northwest. During the first hour of the storm south wind prevailed, during the second hour east, and thereafter northeast throughout the night. The maximum velocity was 31 miles per hour from the south at 7 p. m. The pressure rose 0.15 inch from 7 to 9 p. m., then fell 0.03 inch, rose 0.03 inch, and remained stationary throughout the rest of the night. The temperature dropped from 92° at 6.45 p. m. to 69° at 8 p. m. The direction of movement of the storm appeared to be eastward. This thunderstorm differed from most others at this station in that it showed a slightly greater and more permanent pressure rise, and light continuous precipitation for a longer period of time.

ON THE UNIFORMITY OF SYMBOLS USED IN PUBLICATIONS ON ACTINOMETRY

By ANDERS ÅNGSTRÖM

[Statens Meteorologisk-Hydrografiska Anstalt, Stockholm, Sweden]

The attention of the present author was at first drawn to this matter by Doctor Dobson, who pointed out in a letter the confusion existing as regards symbols, the same symbol being sometimes used even in the same paper for indicating different quantities.

In fact a certain uniformity seems here desirable and also possible to obtain.

As a preliminary step before the matter can be discussed by an international body, I have consulted a number of scientists working in the field of actinometry, and especially I have asked for the opinions of the Meteorological Institute at Potsdam through Doctor Süring, and also for those of Doctor Kimball, formerly president of the radiation commission of the I. G. G. U.

Before giving his own view on the matter, Doctor Kimball refers to the fact that opinions have been expressed against "trying to standardize symbols for actinometric factors, for the reason that we can not get letters that are not already used to indicate factors in some branch of the physical sciences." "Each author should state specifically the meaning of the symbols he employs."

As regards the desirability of stating in each separate case the meaning of the symbols employed, I think there is no diversity of opinion. A certain uniformity will not make such a statement superfluous. But on the other hand I can not attach great weight to the objection that all symbols are already used in some other branch of physical sciences. As natural as it seems that the same author ought to try to use in his various papers the same symbols for the same factors, as reasonable seems also the demand that we ought to aim at a certain uniformity also among various authors.

It is evident that a proposal as regards uniformity of symbols ought not to aim at an alteration of the symbols which are already in use in periodical publications like the Annals of the Astrophysical Observatory, for instance, where a certain uniformity is already created. But the proposal aims at trying to introduce uniformity in all these cases of separate papers and articles, where the lack of uniformity arises simply from the lack of cooperation and accepted rules.

The matter may be regarded as one of inferior importance. And yet it is of considerable weight, just for making ourselves rid of small obstacles in order to have opportunity to concentrate upon the large ones.

As regards some symbols the opinions have gone in various directions. I do not propose to discuss them here. In the following cases however, the opinions seem in general to agree:

1. Intensity of sun radiation $= I$.
   (a) Solar constant $= I_o$.
   (b) Sun radiation within certain spectral intervals: I_r, I_g, $I_{\lambda=540}$, etc.
2. Relative air mass (zenith air mass taken as unit) $= m$.
3. True air mass $= M$; $\left(M = m\frac{b}{760}\right)$ where b is the barometric pressure at the place of observation.
4. (a) $h =$ height of the sun.
   (b) $z =$ zenith distance of the sun.
5. $R =$ effective radiation of long-wave length (generally measured as nocturnal radiation).
6. $D =$ Diffused radiation from the sky.
7. $G =$ atmospheric long-wave radiation.

$$G = \sigma T^4 - R$$

where σ is the constant of Stefan-Boltzmann and T is the absolute temperature.

For the cases where no conflict arises with indications generally accepted for other physical factors, I therefore propose that these symbols be generally used. Especially I have in mind the publications of the observations during the International Polar Year 1932–33.

RETIREMENT OF H. A. HUNT, GOVERNMENT METEOROLOGIST OF AUSTRALIA

A circular, recently received from Melbourne, announces the retirement on February 6, 1931, of H. A. Hunt, Commonwealth meteorologist for Australia.

Mr. Hunt was born in London in 1866. In 1884 he joined the Sydney Observatory staff He was the inventor of the cube pressure anemometer (1902). In 1906 he was made Commonwealth meteorologist, which position he held up to his retirement. Among his published works may be mentioned Types of Australia Weather (1893), and in the succeeding years numerous papers on the climate of Australia.

Mr. Hunt was succeeded by William Shand Watt.—*H. L.*

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING SEPTEMBER 1931

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged below the normal values for September at all three stations at which measurements of direct solar radiation at normal incidence are made.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at New York, Pittsburgh, La Jolla, Fresno, Lincoln, and Chicago, close to the September average at Madison and Gainesville, and a deficiency at Washington and Twin Falls.

Skylight polarization measurements made on 5 days at Washington gave 56 for the mean percentage of polarization with a maximum of 64 on the 9th. At Madison, polarization measurements made on 11 days gave a mean of 61 per cent with a maximum of 71 per cent on the 11th. These are close to the corresponding averages for each station in September.

TABLE 1.—*Solar radiation intensities during September, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Sept. 1	15.11	------	0.58	0.71	------	------	------	------	------	------	16.74
Sept. 4	12.68	------	0.58	0.71	0.93	1.29	------	------	------	------	9.16
Sept. 8	8.81	0.67	0.77	0.91	1.04	1.36	------	------	------	------	6.76
Sept. 9	11.81	0.65	0.78	0.92	1.02	1.19	------	------	------	------	12.68
Sept. 10	17.37	------	------	0.49	0.66	1.07	0.98	0.73	0.61	------	17.37
Sept. 11	18.59	------	------	0.46	0.77	0.98	------	------	------	------	19.89
Sept. 12	19.23	------	------	0.55	0.78	1.05	------	------	------	------	17.37
Sept. 14	16.20	------	0.71	0.70	0.98	1.31	------	------	------	------	17.96
Sept. 18	19.89	------	------	------	------	1.48	------	------	------	------	10.97
Sept. 19	10.21	------	0.63	0.77	0.97	1.24	------	------	------	------	10.59
Sept. 22	21.28	------	------	0.86	1.02	1.17	------	------	------	------	22.00
Sept. 25	6.27	------	------	1.13	1.26	------	------	------	------	------	7.57
Sept. 29	5.70	0.86	0.90	1.13	1.30	1.47	1.22	------	------	------	5.36
Sept. 30	8.48	0.61	0.73	0.90	1.09	------	1.05	0.81	0.71	0.56	8.18
Means	------	0.70	0.72	0.79	0.98	1.24	1.08	(0.77)	(0.66)	(0.56)	------
Departures	------	+0.01	−0.03	−0.07	−0.06	−0.07	+0.03	−0.07	−0.06	−0.10	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during September, 1931*—Con.

Madison, Wis.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 3	9.14	-----	-----	-----	-----	1.25	-----	-----	-----	-----	11.38
Sept. 4	12.24	-----	-----	-----	1.23	1.43	1.23	-----	-----	-----	9.83
Sept. 10	14.60	-----	-----	0.84	1.03	1.34	1.05	-----	-----	-----	13.61
Sept. 11	15.65	-----	0.74	0.88	1.06	1.22	0.97	-----	-----	-----	14.60
Sept. 12	16.20	-----	0.53	0.68	0.80	1.26	-----	-----	-----	-----	13.13
Sept. 14	16.20	-----	-----	0.70	0.86	-----	1.09	-----	-----	-----	17.96
Sept. 16	16.79	-----	-----	-----	-----	1.32	1.11	-----	-----	-----	18.59
Sept 17	14.60	-----	-----	-----	-----	-----	1.22	-----	-----	-----	11.38
Sept. 22	14.60	-----	-----	-----	-----	1.28	1.18	-----	-----	-----	14.10
Sept. 24	6.50	-----	1.10	1.16	1.30	-----	-----	-----	-----	-----	6.76
Sept. 28	7.29	-----	-----	-----	-----	1.51	1.14	1.03	-----	-----	6.76
Sept. 29	7.04	-----	0.69	0.88	1.11	1.40	-----	-----	-----	-----	7.29
Means	-----	-----	0.76	0.86	1.06	1.33	1.12	(1.03)	-----	-----	-----
Departures	-----	-----	−0.14	−0.15	−0.09	−0.04	−0.03	+0.02	-----	-----	-----

Lincoln, Nebr.

Date	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon
Sept. 3	11.81	-----	-----	-----	-----	1.26	0.98	0.77	0.61	0.42	14.10
Sept. 4	13.13	-----	0.66	0.81	0.99	1.31	1.01	0.84	0.70	0.61	11.38
Sept. 5	14.10	-----	0.73	0.88	1.09	1.31	-----	-----	-----	-----	16.20
Sept. 10	12.68	-----	-----	0.90	1.10	1.30	-----	-----	-----	-----	12.68
Sept. 11	14.35	-----	0.75	0.89	1.09	1.38	1.07	0.92	0.79	0.66	13.61
Sept. 12	13.13	-----	0.75	0.88	1.07	1.31	0.92	0.69	-----	-----	13.61
Sept. 16	11.81	-----	0.88	1.01	1.15	-----	-----	-----	-----	-----	15.65
Sept. 18	11.38	-----	-----	-----	-----	-----	1.02	-----	-----	-----	15.11
Sept. 22	8.81	0.84	0.96	1.10	1.27	1.43	-----	-----	-----	-----	10.59
Sept. 25	8.18	-----	-----	1.16	1.31	1.48	-----	-----	-----	-----	8.81
Sept. 26	7.04	-----	1.01	1.20	1.34	1.52	1.31	1.16	1.01	0.92	8.18
Sept. 29	7.87	0.73	0.82	0.94	1.13	1.39	-----	-----	-----	-----	8.74
Means	-----	(0.78)	0.82	0.98	1.15	1.37	1.05	0.88	0.78	0.65	-----
Departures	-----	+0.02	−0.04	−0.02	−0.03	−0.03	−0.09	−0.09	−0.05	−0.08	-----

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
	AVERAGE DAILY TOTALS											
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	400	453	507	350	399	422	401	423	515	335	441	433
Sept. 10	356	355	404	[1] 289	357	413	356	386	510	374	512	326
Sept. 17	310	249	326	[2] 316	306	321	363	[3] 502	506	367	488	312
Sept. 24	323	295	453	322	350	373	279	[4] 426	450	336	381	373
	DEPARTURES FROM WEEKLY NORMALS											
Sept. 3	+21	+81	+85	+36	+85	−98	+55	+13	−7	−14	-------	
Sept. 10	−18	+9	−2	−6	+53	−79	+2	−31	+14	+55	-------	
Sept. 17	−42	−90	−58	+39	+18	−140	+28	+53	+49	+43	-------	
Sept. 24	−22	+4	+101	+82	+82	−57	−16	−22	+21	−14	-------	
Accumulated departures on Sept. 30, 1931	−471	+3,143	+1,652	+217	+476	−5,788	−1,611	----	+339	−6,503	-------	

[1] Mean for 4 days. [2] Mean for 6 days. [3] Mean for 5 days. [4] Mean for 4 days.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1931	*h* *m*	°	°	°			
Sept 1 (Naval Observatory)	10 47	−41.0	345.5	+4.0	12	------	------
		−12.5	14.0	+12.0	------	108	------
		−1.5	25.0	+2.0	31	------	151
Sept. 2 (Naval Observatory)	10 43	−70.0	303.4	−6.0	3	------	------
		+2.0	15.4	+11.5	------	93	------
		+11.0	24.4	+2.0	31	------	127
Sept. 3 (Perkins Observatory)	10 22	+18.5	18.9	+9.0	93	------	------
		+26.0	26.4	+1.5	93	------	186
Sept 4 (Naval Observatory)	10 45	−42.0	304.9	−6.0	9	------	------
		+21.0	7.9	+11.0	------	25	------
		+31.5	18.4	+10.0	------	31	------
		+39.0	25.9	+2.0	31	------	96
Sept. 5 (Naval Observatory)	10 43	+46.0	19.7	+11.5	15	------	------
		+51.0	24.7	+2.5	31	------	46
Sept. 6 (Naval Observatory)	10 41		No spots				
Sept. 7 (Naval Observatory)	10 41	+1.5	308.8	−5.5	9	------	9
Sept. 8 (Naval Observatory)	10 42	+16.0	310.1	−6.0	9	------	9
Sept. 9 (Naval Observatory)	10 43	−70.5	210.4	−20.0	6	------	------
		−42.5	238.4	−9.5	31	------	------
		+28.0	308.9	−7.5	------	25	62
Sept. 10 (Naval Observatory)	10 42	−28.3	239.4	−9.7	19	------	------
		+42.0	309.7	−7.0	------	77	96
Sept. 11 (Naval Observatory)	10 42	−13.2	241.3	−9.2	12	------	------
		+31.5	286.0	+8.7	31	------	------
		+58.2	312.7	−8.0	------	123	166
Sept. 12 (Naval Observatory)	10 36	−3.0	238.4	+9.5	------	37	------
		+71.0	312.4	−8.0	------	154	191
Sept. 13 (Naval Observatory)	10 36	−69.5	158.7	+3.0	6	------	------
		+11.0	239.2	+9.0	------	62	68
Sept. 14 (Naval Observatory)	10 37	−56.0	159.0	+4.0	------	37	------
		+24.8	239.8	+9.4	------	74	------
		+55.0	270.0	+17.0	12	------	123
Sept. 15 (Naval Observatory)	13 36	−40.3	159.8	+3.3	31	------	------
		+39.0	239.1	+9.0	------	87	118
Sept. 16 (Naval Observatory)	12 13	−73.0	114.7	+9.0	------	154	------
		−26.5	161.2	+3.3	25	------	------
		+51.0	238.7	+9.2	------	129	308
Sept. 17 (Naval Observatory)	12 27	−57.8	116.5	+8.6	------	93	------
		−12.2	162.1	+3.0	------	12	------
		+8.7	183.0	+19.9	15	------	------
		+63.6	237.9	+8.2	------	74	194
Sept. 18 (Naval Observatory)	10 49	−45.0	117.0	+8.0	------	77	------
		+75.0	237.0	+7.0	6	------	83
Sept. 19 (Naval Observatory)	10 42	−31.0	117.9	+8.0	68	------	68
Sept. 20 (Mount Wilson)	18 30	−36.0	95.4	+9.5	4	------	------
		−13.0	118.4	+9.0	------	112	116
Sept. 21 (Naval Observatory)	10 37	−4.5	118.0	+8.1	------	50	50
Sept. 22 (Naval Observatory)	10 34	−14.0	95.4	+8.0	------	93	------
		+9.0	118.4	+7.6	------	56	149
Sept. 23 (Naval Observatory)	10 16	0.0	96.3	+6.0	------	62	------
		+22.0	118.3	+7.0	31	------	------
		+37.0	133.3	−3.0	12	------	105
Sept. 24 (Naval Observatory)	10 40	+11.5	94.4	+5.5	------	31	------
		+38.0	120.9	+7.5	19	------	50
Sept. 25 (Naval Observatory)	10 40	+50.5	120.2	+7.5	9	------	9
Sept. 27 (Naval Observatory)	10 35	−85.0	318.4	+8.7	62	------	------
		−26.5	16.9	+4.5	------	12	------
		−10.0	33.4	+6.5	------	15	89
Sept. 28 (Naval Observatory)	11 22	−75.0	314.7	+8.5	------	123	123
Sept. 29 (Naval Observatory)	10 44	−59.0	317.9	+18.5	123	------	------
		−68.5	308.4	+18.5	46	------	169
Sept. 30 (Naval Observatory)	10 44	−53.5	310.2	+18.5	108	------	------
		−45.0	318.7	+18.7	37	------	145
Mean daily area for September	------	------	------	------	------	------	107

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR SEPTEMBER, 1931

(Dependent alone on observations at Zurich and its station at Arossa)

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich Switzerland]

September, 1931	Relative numbers	September, 1931	Relative numbers	September, 1931	Relative numbers
1	33	11	29	21	*a* 10
2	*a* 27	12	Mc 23	22	Mc 22
3	27	13	27	23	22
4	19	14	26	24	16
5	15	15	*d* 19	25	7
6	15	16	27	26	7
7	14	17	28	27	15
8	18	18	26	28	*d* 17
9	13	19	11	29	10
10	Ec 24	20	------	30	11

Mean; 29 days = 19.2.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group or spot through the central meridian.
c = New formation of a center of activity: E, on the eastern part of the sun's disk; M in the central zone.
d = Entrance of a center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in charge]

By L. T. SAMUELS

Free-air temperatures were decidedly above normal at Chicago, Cleveland, Dallas, Ellendale, Omaha, and Washington, with the greatest departures therefrom occurring at Omaha at 2,000 and 2,500 meters. At Due West the departures were small and negative at the higher levels. Normal temperatures for Hampton Roads, Pensacola, and San Diego are not available.

In connection with the large positive temperature departures at Omaha it will be noted from Table 2 that the resultant wind movement for the month based on 7 a. m. observations contained a large southerly component as compared with the resultants at Chicago and Cleveland, in practically the same latitude.

The relative humidity departures from the normal were mostly negative at the lower levels and positive at the higher levels.

The free-air resultant wind directions for the month at the 1,000-meter level were close to normal, while the resultant velocities were considerably in excess of the normal at most stations. At 3,000 meters the resultant directions were close to normal at the northern stations but differed appreciably at a number of southern and west coast stations. In most cases where the monthly resultant direction varied from the normal the resultant velocity was below normal.

From Table 3 it will be noted that airplane observations were obtained at all four stations on every day during the month. The maximum altitude reached was 7,018 meters above sea level at Omaha on the 13th.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during September, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (2 meters)	Omaha, Nebr.[1] (299 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)	Washington, D. C.[3] (2 meters)
Surface	17.3	17.1	23.3	23.4	18.0	24.1	18.4	24.6	21.4	21.0
500	18.2	18.4	24.1	21.5	17.9	22.3	19.1	23.7	17.8	21.2
1,000	17.9	17.5	23.4	18.7	16.9	19.9	20.8	21.2	19.0	19.7
1,500	16.1	15.1	21.2	15.7	14.7		19.6			
2,000	13.8	12.5	18.3	13.0	12.2	14.4	17.0	15.5	15.8	14.5
2,500	10.9	10.0	15.5	10.1	9.5		13.9			
3,000	8.1	7.6	12.7	7.4	6.3	8.1	10.5	9.7	9.8	9.0
4,000	1.9	2.4	5.9	0.8	−0.3		3.7	1.7		2.9
5,000	−4.3	−2.8	0.3	−5.4	−6.9		−3.1			
6,000		−7.2	−3.9		−12.6		−9.9			
7,000							−18.4			

RELATIVE HUMIDITY (PER CENT)

Altitude (meters) m. s. l.	Chicago	Cleveland	Dallas	Due West	Ellendale	Hampton Roads	Omaha	Pensacola	San Diego	Washington
Surface	85	84	71	73	61	72	78	86	69	78
500	74	74	66	70	60	67	72	76	76	65
1,000	64	67	59	68	52	66	57	72	50	59
1,500	58	63	59	66	51		53			
2,000	55	59	58	62	52	58	53	64	28	56
2,500	56	54	55	57	52		53			
3,000	54	48	54	53	54	46	55	56	21	53
4,000	53	44	54	55	58		53	52		54
5,000	47	45	42	66	59		50			
6,000		95	75		57		47			
7,000							74			

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a. m. (E. S. T.) during September, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 28 E	0.5	S 66 E	0.9	S 2 W	1.9	N 86 W	3.5	S 17 W	1.5	S 13 W	1.6
500			S 46 E	6.2	S 62 W	3.4			S 50 W	6.5	S 62 W	5.6
1,000			S 36 E	6.5	N 71 W	6.3			S 72 W	6.6	S 84 W	6.9
1,500			S 43 E	5.6	N 67 W	9.0			S 89 W	6.8	S 87 W	7.4
2,000	S 27 W	2.4	S 51 E	5.1	N 44 W	11.3	S 87 W	5.4	N 89 W	8.3	S 86 W	7.8
2,500	S 58 W	3.5	S 76 E	4.7	N 43 W	12.6	S 80 W	7.7	N 73 W	7.9	W	9.0
3,000	S 58 W	5.3	S 82 E	5.4	N 52 W	11.6	S 84 W	8.0	N 69 W	8.1	N 80 W	9.8
4,000	S 63 W	6.3	N 45 E	6.5			S 86 W	7.6	N 64 W	8.6	N 78 W	9.3
5,000	S 59 W	5.9					S 82 W	7.6			S 85 W	8.1

Altitude (meters) m. s. l.	Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 27 E	2.0	N 41 E	0.7	N 81 W	1.0	S 84 W	0.9	N 17 W	1.3	S 79 E	2.1
500	S 17 W	8.5	N 15 W	1.1	S 85 W	0.9			N 65 E	3.8	S 72 E	5.4
1,000	S 17 W	8.2	N 13 E	1.2	S 54 W	3.0	S 85 W	2.6	S 84 E	3.1	S 68 E	4.9
1,500	S 13 W	4.8	N 27 E	1.5	S 82 W	5.6	N 75 W	5.0	E	3.1	S 76 E	4.4
2,000	S 13 W	3.5	N 11 W	0.9	S 89 W	6.3	N 85 W	5.3	N 86 E	3.3	S 77 E	3.4
2,500	S 11 W	2.4	N 4 E	1.2	S 87 W	8.2	S 83 W	6.2	N 79 E	4.1	S 83 E	3.9
3,000	S 30 E	1.0	N 13 W	2.1	S 81 W	9.8	S 70 W	6.9	N 77 E	3.6	S 89 E	4.2
4,000	N 9 E	1.8	N 37 W	2.9	N 86 W	11.1			N 57 E	3.9	N 80 E	4.3
5,000			N 40 W	3.5	N 87 W	10.3			N 31 E	2.1	N 60 E	3.3

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 23 E	0.7	S 31 W	0.1	S 5 W	1.3	N 42 E	1.0	S 45 E	0.2	S	3.5
500	S 89 E	0.8	S 61 W	0.3	S 47 W	4.9	N 89 E	2.4	N 39 W	2.5	S 12 W	7.9
1,000	S 76 E	0.7	N 79 W	0.8	S 50 W	4.5	S 57 E	2.5	N 1 E	3.6	S 31 W	13.9
1,500	S 50 W	1.1	S 24 E	0.6	S 49 W	4.3	S 49 E	2.9	N 5 W	1.8	S 46 W	9.4
2,000	S 24 W	2.9	S 37 W	0.6	S 38 W	3.0	S 62 E	2.9	N 12 W	3.1	S 43 W	6.2
2,500	S 39 W	4.3	S 71 W	2.4	S 31 W	4.2	S 71 E	2.5	N 15 W	4.4	S 46 W	3.8
3,000	S 33 W	5.1	N 86 W	3.2	S 27 E	1.4	N 83 E	1.0	N 14 W	4.7	N 32 W	1.3
4,000			N 44 W	3.3			N 42 E	2.0			N 3 W	1.6
5,000							N 82 E	1.5				

Altitude (meters) m. s. l.	Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 37 E	1.7	S 85 E	1.6	S 28 E	3.5	N 33 E	0.3	S 31 E	1.5	N 50 W	0.5
500	S 1 W	4.5	S 69 E	1.7			N 86 W	2.5	S 45 W	2.7	N 58 W	2.9
1,000	S 40 W	11.6	S 15 E	0.5			N 76 W	6.2	S 40 W	2.6	N 53 W	4.3
1,500	S 49 W	10.4	S 26 W	2.1	S 12 E	5.5	N 76 W	6.9	S 66 W	1.5	N 62 W	5.8
2,000	S 53 W	9.1	S 14 W	3.6	S 13 W	5.0	N 70 W	7.3	N 83 W	0.9	N 67 W	6.9
2,500	S 70 W	6.2	S 20 W	5.8	S 35 W	4.3	N 74 W	9.2	N 6 E	2.7	N 68 W	6.1
3,000	S 48 W	5.7	S 26 W	6.6	S 50 W	5.4	N 68 W	10.7			N 75 W	6.3
4,000	S 59 W	2.8			S 68 W	7.6	N 72 W	10.7			N 89 W	4.8
5,000					S 88 W	4.5						

TABLE 3.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during September, 1931.*

	Dallas, Tex.[1]	Due West, S. C.	Ellendale, N. Dak.	Chicago, Ill.[1]	Cleveland, Ohio[1]	Omaha, Nebr.[1]
Mean altitudes (meters), m. s. l., reached during month	5,625	2,747	3,245	5,070	5,688	6,528
Maximum altitude (meters), m. s. l., reached	6,013	[3] 5,431	[2] 6,324	5,519	6,089	7,018
Number of flights made	30	30	31	30	30	30
Number of days on which flights were made	30	29	29	30	30	30

[1] Airplanes. [3] Limited-height sounding balloon flights.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

[Climatological Division, OLIVER L. FASSIG, in Charge]

By M. C. BENNETT

GENERAL SUMMARY

September was abnormally warm—generally 4° to 10° above normal—east of the Rocky Mountains except in some extreme northeast and southern localities where the monthly averages were near the normal. West of the Rocky Mountains the temperatures were slightly above normal, except at a few stations in the Pacific coast districts which reported small deficiencies. Considering the entire country, it was the warmest September of record. Previous maxima for September were equaled or broken in many places from the northern Great Plains eastward, 104° being reported as far north as Minneapolis.

The monthly precipitation was very unequally distributed. More than normal was received north of the Ohio and lower Missouri Rivers, some sections receiving 100 per cent above normal for September. Large excesses above normal likewise occurred in portions of the Rocky Mountains area, the Pacific Northwest, and in southern Florida. Elsewhere there was a general deficiency. A large portion of the lower Mississippi Valley and much of the Southwest received less than 25 per cent of the normal, and the deficiencies were nearly as marked in the South Atlantic, western Great Plains, and central Pacific areas.

TEMPERATURE

The first week of September was warmer than normal in most portions of the country, particularly in the Plains States and the northern half of the Rocky Mountain region. Large portions of the Ohio Valley and the lower Lake region had practically normal temperatures this week. The fortnight from the 8th to the 21st was remarkably warm for September from the interior of the Middle Atlantic States westward and southwestward to the upper Mississippi Valley and the middle and southern Plains, and also moderately warmer than normal in New England, the South, the Dakotas, and most portions of the Rocky Mountain States, save Montana. In the far West this period was generally cooler than normal.

From the 22d temperatures generally were lower than they had been during the previous two weeks, the change progressing from the Northwest into the East and South, where some States had three or four days at the end of the month with temperatures lower than normal. The final 9-day period averaged cooler than normal in most north-central and northwestern areas, but warmer over much more than half the country; though the departure was generally small except from the lower Mississippi Valley westward to southern California, where it was usually +3° to +9°.

The month as a whole was probably the warmest September in the history of the weather service. From Colorado eastward to the Middle Atlantic States many States and numerous single stations report it the hottest September within the period available for computation, which is usually from 35 to 50 years. From South Dakota to Oklahoma the month averaged 7° to 9° hotter than normal, and practically everywhere else east of the Rocky Mountains from 3° to 6° hotter, save in much of Florida, New Hampshire and Maine where it was only about normal. Generally in Arizona, Utah, Idaho, Washington, and western Montana the month averaged a little warmer than normal, but in Nevada, southern Oregon, and northern and central California a little cooler.

The highest marks were 100° or above in most States, and in some eastern cotton States even 106° or 107°. Minnesota and several Plains States reported from 110° to 112°, but the very highest was 115° at Gila Bend, Ariz., on the 11th and again on the 28th. In the western half the highest readings occurred generally during the opening week, but in the eastern half either about the 11th or about the 18th. From Montana eastward to New England several stations noted marks higher than any of previous September record.

The lowest readings in some Gulf States were above 40°, but in other States east of the Rocky Mountains between 40° and 25°. In the far West many high mountain stations reported lower temperatures, 8° being noted at a Wyoming station on the 23d. Lowest marks occurred largely about the 9th or about the 23d in the western half of the country, but in the eastern half usually during the final four days.

PRECIPITATION

The first week in September brought heavy rains to parts of the Florida Peninsula and to western Washington, most of the central valleys, the Ohio Valley, and large portions of New York and New England. The second week was mainly a period of little or no rainfall, though much of Florida and Michigan received considerable. The third week brought needed rains from northern Oklahoma and the eastern parts of Kansas and Nebraska northeastward to northern Michigan, also to northern New England and New York, and a large part of North Dakota.

The final 9-day period of the month was the time of best-distributed rainfall for the northern and central sections east of the Rocky Mountains, though there was heavy rainfall over most of Iowa and northern Missouri and the southwestern part of Wisconsin.

The distribution of the monthly precipitation was uneven and was notably scanty in nearly all of the South and a large part of the Plains. In Florida the situation was particularly diverse, Miami having the wettest September of record, while Jacksonville had the driest.

From South Carolina, Georgia, and northern Florida westward to include Arkansas and Louisiana there was very little rainfall and little also in southern and western Texas, and thence northward over the western Plains to the Black Hills area.

There was mainly much less rainfall than normal in southern Virginia and from New Jersey to Massachusetts.

More than normal rainfall occurred in the southern half of Florida, Miami measuring 19.70 inches. The Lake region received considerably more than normal and the Ohio Valley, somewhat more than normal, save the southwestern portion. Most of the upper Mississippi and lower Missouri Valleys had considerably more than normal, one Iowa station reporting 12.68 inches. From northern New Mexico to northwestern Montana the vicinity of the Continental Divide had usually more precipitation than normal, and the northern and western portions of Washington also had more than normal, one station in western Washington measuring 16.32 inches.

Several Western States report appreciable snowfall in their high mountain areas. Most of this snow occurred not long before the end of the month.

SUNSHINE AND RELATIVE HUMIDITY

More than the average amount of sunshine was received generally throughout the country during September, except in the far Northwest, much of the Lake region, northern New England, and southern Florida, where less than the usual amount prevailed. It was particularly large in the south-central Great Plains and eastward to the Atlantic. In the southern portion of the Florida Peninsula the daytime sky was only 27 per cent clear, while in some sections of the northern portion of that State it was 70 per cent clear.

The relative humidity was above normal in the Ohio Valley, the Lake region, the far Southwest and southern Florida. Elsewhere, it was generally below the average, with departures mostly small, except in the central Great Plains where they were rather pronounced.

SEVERE LOCAL STORMS, SEPTEMBER, 1931

[The table herewitb contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of patb (yards)	Loss of life	Value of property destroyed	Cbaracter of storm	Remarks	Authority
Eureka, Mo., and vicinity	1	5:15 p m	100		$25,000	Tornado	Buildings and other property damaged; 5 persons injured; path 1 mile long.	Official, U. S. Weather Bureau.
Knoxville, Tenn	2	2:29 p. m			2,000	Thunderstorm	Tower destroyed by lightning; power and telephone service impaired.	Do.
Reading and Berks County, Pa.	2	P. m			25,000	Electrical and rain	Barns and sheds burned; highways blocked by broken trees; heavy property damage at Mertztown	
Lebanon, Ind. (6 miles southwest).	3				7,500	Electrical	Barn and contents burned	Do.
Shelbyville, Ind. (2 miles east).	3				20,000	do	A hangar, 4 planes, 3 trucks, and a tractor burned.	Do.
Muskingum and Noble Counties, Ohio.	4	P. m			10,000	Hail	Considerable damage to crops and buildings	Do.
Grand Rapids (near), Mich.	4				25,000	Electrical	Amusement park and church damaged by lightning.	Do.
Port Artbur, Tex	5					Wind and rain squal.	Trees uprooted; tanker broke away from dock causing some damage.	Do.
Atoka, Okla	6	5 p. m	440	1		Wind	Ball park grandstand demolished; roofs torn off; windows broken; wires and trees blown down; path 2 miles long; 4 persons injured.	Do.
Palermo, Me	6	P. m				Probably tornado	Buildings demolished or moved; several persons hurt.	Washington (D. C.) Post.
La Porte, Tex	10	3 p. m				do	Timber and awnings damaged in bay-shore area.	Official, U. S. Weather Bureau.
Cascade and Teton Counties, Mont.	10					Hail	Chief damage to crops	Do.
Dane, Jefferson, Waukesha, Milwaukee, Ozaukee, Door, Brown, and Calumet Counties, Wis.	12	2:30 - 5:30 p. m.			217,000	Wind and thunderstorms.	Wires, poles, trees, and signs blown down; windows broken; barns wrecked.	Do.
Adrian, Mich	12					Rain, hail, and wind.	Light poles, trees, and other property considerably damaged.	Do.
Glacier County, Mont	12					Hail	Crops damaged	Do.
Fayette and Ross Counties, Ohio.	14–17			1		Wind, electrical and rain.	Much damage to property by flooding; several injured and 45 stunned by lightning.	Do.
Canton, N. Y. (vicinity of)	15				10,000	Electrical	Large barn and other buildings burned or damaged.	Do.
Thornburg, Kans. (3 miles southeast).	18	6:30 p. m				Tornado	Number of farm buildings wrecked; path 4 miles long.	Do.
Knoxville (near), Tenn	19	2:50 p. m			8,000	Thunderstorm	Barn and contents burned; farm machinery damaged.	Do.
Hanlontown (near), Iowa	19	7:30 p. m			3,200	Tornado	Buildings damaged; livestock killed; path 5 miles long.	Do.
Clay and Palo Alto Counties, Iowa.	19	P. m			12,000	Wind and rain	Trees, small buildings, windmills and electric wires damaged; some small buildings wrecked.	Do.
Crawford and Humboldt Counties, Iowa.	19					Wind	Roofs and chimneys damaged; corn blown down.	Do.
Linn and Sioux Counties, Iowa.	19					Rain and flood	Sewers flooded; railroad washed out; train derailed.	Do.
Buena Vista County, Iowa.	20	4-4:10 p.m.	1,760		5,000	Hail	Windows and auto tops pierced; corn injured	Do.
Slaton (near), Tex	20	8:15 p. m	3,520		30,000	Wind	Chief damage to buildings; some crop injury; path 20 miles long.	Do.
Cass and Monona Counties, Iowa.	20				12,000	Wind and hail.	Auto tops, roofs and windows pierced; corn injured; electric wires damaged.	Do.
Grantsburg, Wis	20					Hail	Crops and trees considerably damaged	Do.
Tama County, Iowa	20					Wind	Awnings and store fronts damaged; small buildings demolished; 20 electric poles blown down.	Do.
Davis County, Iowa	21	3:15-3:30 p. m.	100		400,000	Tornado, wind and hail.	Trees mutilated; houses, harns and windmills wrecked; 600 homes unroofed; overhead wires damaged; 20 persons injured; path 11 miles long.	Do.
Van Buren, Jefferson, Henry, Washington, and Louisa Counties, Iowa.	21	3:30-4:30 p. m.	33-100	2	125,000	Tornado	Damago confined to rural districts; overbead wires damaged; livestock killed; 8 persons injured; path 50 miles long.	Do.
Labette, Cherokee and Crawford Counties, Kans.	21	4:10-4:30 p. m.	880	2	50,000	do	Practically every building at Oswego fair grounds damaged; heavy property damage elsewhere; path 35 miles long.	Do.
Lamar (near), Mo	21	5 p. m	1,760		2,000	Small tornado	Barn, silo and some small sheds blown down	Do.
Poweshiek County, Iowa	21	do			8,000	Wind	Farm buildings and trees damaged; airplane wrecked.	Do.
Scott County, Iowa	21	5:30 p. m			5,000	Hail and wind	Roofs and windows pierced; corn stripped	Do.
Garnett, Okla. (2 miles northwest).	21	7 p. m	200		1,200	Wind	Damage to property other than crops; path 4 miles long.	Do.
Columbia, Mo. (southern part).	21	do	2 blocks		20,000	Small tornado	City and university buildings damaged; 1 person injured.	Do.
Stordville (near) to Oconomowoc, Wis.	21	7:30-9 p. m.	200	1	300,000	Possibly 2 tornadoes.	Many farm buildings wrecked; crops ruined; over 40 families reported homeless or in need of aid; 9 persons injured; path 50 miles long.	Do.
Pittsfield, Ill	21				10,000	Wind	Poles and trees blown down; roofs damaged; wire service temporarily cut off.	Do.
Overbrook, Kans., and vicinity.	22	4:10 p. m	1,760		3,000	Tornadic wind	Farm buildings, growing crops and telephone wires damaged; path 2.5 miles long.	Do.
Butler County, Iowa	23	4:30 p. m			4,000	Wind	Several small buildings and roofs damaged; trees uprooted; auto tops torn; 2 persons injured.	Do.

Severe local storms, September, 1931—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
New Mexico (northern Rio Grande area).	23-24					Floods	Highways, railway, fields and crops damaged; homes flooded.	Official, U. S. Weather Bureau.
Norway (near), Kans	24	7:30 p. m.	880		5,000	Tornado and hail	Livestock killed; crops injured; 10 persons hurt; path 8 miles long.	Do.
Rush County, Ind. (central).	25	2 p. m.	440-880			Thunderstorm and wind.	Considerable damage to buildings; telephone service interrupted.	Do.
Boston, Ind	25	2:45 p. m.	100-130		100,000	Tornado	2 school buildings and a number of dwellings damaged; crops hurt; 25 persons injured.	Do.
Grayville (near), Ill	25				4,500	Wind	Buildings damaged	Do.
Anderson, S. C	26	A. m.			10,000	Thunderstorm	Several barns and contents destroyed by lightning.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

[In charge River and Flood Division]

Local overflows in small streams occurred in September in northwestern New York, Ohio, Michigan, Wisconsin, and New Mexico. The resulting damage was of minor consequence. A few rivers rose to stages slightly above bankful, as shown in the following table, but the only damage reported was in New Mexico, near Espanola, where there was estimated damage of $1,500 to highways, and $500 to crops:

Table of flood stages in September, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	Feet			Feet	
Roanoke: Williamston, N. C	9	[1] 26	1	9.9	[1] 31
Peedee: Poston, S. C	18	[1] 29	1	18.9	[1] 31
MISSISSIPPI SYSTEM					
Missouri Basin					
Big Blue: Blue Rapids, Kans	20	25	26	20.8	25
Grand:					
Gallatin, Mo	20	26	26	23.3	26
Chillicothe, Mo	18	26	27	20.8	26
Ohio Basin					
White, West Fork: Edwardsport, Ind	10	17	18	12.0	18
WEST GULF OF MEXICO DRAINAGE					
Rio Grande: Espanola, N. Mex	7	24	24	8.1	24

[1] In August.

All datos are in September, unless otherwise indicated.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By tho Marine Division, W. F. McDONALD in charge]

PRELIMINARY NOTE

The most important feature of the weather of the month from the marine standpoint was the occurrence of an unusual number of tropical disturbances, seven in American waters and at least four in Asiatic waters. The American group affected the Caribbean area, the Yucatan Peninsula, Mexico, and the Pacific coastal waters adjacent to Mexico, with one hurricane producing a major disaster at Belize, British Honduras, on September 10. Special articles appear elsewhere in this issue covering the American disturbances and the first of the typhoons. The discussion has therefore been limited to brief mention in those cases below.

NORTH ATLANTIC OCEAN

By W. F. McDONALD

The pressure situation.—Average pressures for the month of September were much above normal in the region of the northeastern Atlantic, with the Shetland Islands apparently at the center of the pressure anomaly. On the other hand, the barometer averaged lower than normal over much of the western Atlantic, centering about Newfoundland and Nova Scotia, with the Gulf and West Indies showing a slight excess of pressure north of the twentieth parallel of latitude and a slight deficiency in the Caribbean Sea and Central America.

In so far as the averages for the month may be said to have significance, they represent a displacement of the normal North Atlantic HIGH northeastward, with a corresponding displacement of the LOW center of action to westward, so that the latter (resulting in fact from the combination of several separate movements of centers of low barometric pressure) obtained sway over the region of the northwestern Atlantic, Greenland, and Labrador. The mid-Atlantic HIGH was seldom well developed in the region between the Azores and Bermuda, the crest of this ridge probably being displaced southward during much of the month.

Early in the month, the movement of LOWS into the Atlantic was on an unusual track, almost due eastward along the latitude of 40°, the disturbances being as a rule but weakly developed, but nevertheless persistent in their progress eastward over the area normally occupied by well-developed HIGH formations. After the 6th a persistent HIGH was set up over the British Isles that lasted almost continuously until the 30th.

Beginning about the 10th, the LOWS over the northwestern Atlantic and adjacent land areas became more intense and in general moved slowly northeastward, crossing Greenland and passing mostly to the northward of Iceland. These developments culminated in an exceptionally deep cyclonic depression, season considered, which was central over the Strait of Belle Isle on the 25th, with minimum pressure below 29 inches.

Charts VIII to XI, in this issue, cover four of the daily pressure situations over the Atlantic in September, the first three giving the general setting for hurricane movements, and the last showing the conditions attending the stormiest day of the month, in point of number of gales reported, on the main northern trans-Atlantic steamer routes. Table 1 gives some details of the monthly barometric pressures.

Gales and tropical disturbances.—Three tropical storm movements crossed the Caribbean area in the month, these being discussed at length in a separate article in this number of the REVIEW. It is worthy of note here, however, that no ship reporting to this bureau encountered winds of hurricane force in connection with these storms in the open sea on the Atlantic side of the continent, the hurricane damages being inflicted on the coasts as the storms passed.

Most of the gale reports on the main trans-Atlantic steamer routes appear on the 23d to 25th, at which time winds of force 8 to 9 were encountered quite generally over the area between 30° and 60° W. longitude and north of 45° latitude.

Fog.—Fog continued to decrease over the North Atlantic, being confined mostly to the vicinity of the Grand Banks where it was reported in places on about 25 per cent of the days of the month, with some fog off the entrance to New York Harbor on the 5th, 12th, and 13th. A brief spell of rather extensive fogginess, on the 17th and 18th, was encountered between mid-Atlantic and the British Isles.

Trans-Atlantic aviation.—The only attempt at a crossing of the Atlantic by airplane during September was the Rody-Johanssen-Viega flight westward from Portugal, beginning on the morning of the 13th. The plane was sighted over the Azores on its way out into midocean on a course toward Nova Scotia, and after 33 hours was sighted again, about 400 miles east of Halifax, by the steamship *Pennland*. The flyers were forced down, however, without making land, and were rescued only after floating at sea for a week, being picked up by the Norwegian motor ship *Belmoira* off Newfoundland on the 22d. The situation on the 14th, when the flyers were forced down, is depicted on Chart X.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, September, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland [1]	29.89		30.36	1st	29.24	29th.
Reykjavik, Iceland [1]	29.95	+0.22	30.39	20th	29.24	29th.
Lerwick, Shetland Isles [1]	30.10	+0.26	30.57	21st	29.71	3d.
Valentia, Ireland [1]	30.22	+0.23	30.62	26th	29.44	3d.
Lisbon, Portugal [1]	30.05	+0.03	30.27	12th	29.87	23d.
Madeira [1]	30.04	+0.03	30.23	26th	29.84	23d.
Horta, Azores [1]	30.15	−0.02	30.39	11th	29.79	6th.
Belle Isle, Newfoundland [1]	29.80	−0.10	30.24	17th	28.96	26th.
Halifax, Nova Scotia [1]	29.91	−0.14	30.22	do	29.46	25th.
Nantucket [2]	29.98	−0.10	30.48	30th	29.52	24th.
Hatteras [2]	30.06	0	30.47	do	29.70	27th.
Bermuda [1]	30.07	−0.01	30.22	22d	29.86	29th.
Turks Island [1]	30.02	+0.04	30.08	26th	29.94	18th.
Key West [2]	29.95	+0.01	30.13	30th	29.80	9th.
New Orleans [2]	30.02	+0.04	30.23	do	29.84	8th.
Cape Gracias, Nicaragua [1]	29.84	−0.07	29.90	20th	29.74	19th.

[1] All data based on a. m. observations only, with departure computed from best available normals related to time of observation.
[2] Corrected 24-hour means, based on more than one observation daily.

OCEAN GALES AND STORMS, SEPTEMBER, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
amaica Pioneer, Br. S.S.	Kingston, Jamaica.	Rotterdam	43 04 N	40 44 W	Sept. 2	2 p., 2	Sept. 4	29.92	ESE		ESE	ESE, 8	Steady.
ity of Alton, Am. S. S.	Rotterdam	New York	50 12 N	6 30 W	Sept. 3	2 a., 4	do	29.38	NW	NW, 8	NW	NW, 8	Do.
rave Coeur, Am. S. S.	New Orleans	London	49 25 N	16 30 W	do	6 a., 3	Sept. 3	29.65	N	NE, 9	N	NE, 9	N-NNE-N.
ity of Alton, Am. S. S.	Rotterdam	New York	51 00 N	26 50 W	Sept. 7	8 a., 7	Sept. 7	29.68	SE	SE, 8	SE	SE, 8	Steady.
llinois, Am. S. S.	San Pedro	Providence, R. I.	15 20 N	76 28 W	Sept. 8	9 a., 8	Sept. 8	29.53	NE	NE, 11	ESE	NE, 11	NE-E.
resident McKinley, Am. S. S.	New York	Cristobal	16 07 N	81 45 W	Sept. 9	1:30 p., 9	Sept. 9	29.38	E	SSE, 10	S	E, 11	E-SE.
tenas, Am. S. S.	New Orleans	Port Limon and return.	16 39 N	83 00 W	do	5 p., 9	do	29.49	E	E, 9	SE	SE. 9	E-SE.
eredia, Am. S. S.	do	Puerto Barrios, etc.	16 49 N	87 00 W	Sept. 10	11:30 a., 10	Sept. 10	29.60	WSW	S, 10	SE	—, 10	WSW-SE-S.
atun, Hond. S. S.	do	Ceiba, Honduras, and return.	18 19 N	86 42 W	do	1 p., 10	do	29.74	E	ESE, 9	SE	ESE, 9	E-S-ESE-SE.
ilwaukee, Germ. M. S.	Cobh	New York	47 10 N	39 20 W	Sept. 11	9:24, 11	Sept. 11	29.75	SSE	S, 8	SSW	S, 8	SE-S-SW.
Do	do	do	46 00 N	42 58 W	Sept. 12	9:12, 12	Sept. 12	29.40	SW	S, 8	W	S, 8	SW-S-W.
mbridge, Am. S. S.	Rotterdam	do	50 20 N	30 47 W	do	4 p., 15	Sept. 16	29.91	W	SSW, 7	WSW	S, 8	WSW - SSW - SW.
mapala, Hond. S. S.	Ceiba	do	19 20 N	85 50 W	Sept. 14	1 a., 14	Sept. 14	29.85	NNE	NE, —	ESE	—, 8	NNE-ESE.
ytheville, Am. S. S.	Rotterdam	do	49 00 N	40 52 W	Sept. 22	5:20 a., 23	Sept. 24	28.87	E	NNW, 9	W-N	NW, 9	E-SE-NW.
ollamer, Am. S. S.	Bordeaux	do	48 25 N	39 15 W	Sept. 23	4 p., 23	do	29.11	SSW	WNW, 8	W	WNW, 9	SW-W-WNW.
uropa, Germ. S. S.	Cherbourg	do	48 49 N	27 22 W	do	6:00, 24	do	29.61	S	SSE, 9	W	SE, 9	6 points.
elgenland, Br. S. S.	New York	Plymouth	47 47 N	31 22 W	do	4 p., 23	do	29.37	S	SSE, 7	SSE	SSE, 9	Steady.
ameronia, Br. S. S.	Glasgow	New York	50 20 N	43 40 W	do	9 a., 23	do	29.17	ENE	NNW, 9	W	NNW, 9	NE-N-NNW.
iger, Norw. Tk. S. S.	Baton Rouge	Bergen	52 59 N	41 12 W	do	9:30 a., 24	do	28.65	N	WNW, 3	WNW	NNW, 9	N-WNW.
la, Am. S. S.	Antwerp	Baltimore	50 39 N	26 24 W	do	6 a., 24	Sept. 23	29.64	SE	SE, 8	S	SE, 9	SE-S-SSW.
iger, Norw. Tk. S. S.	Baton Rouge	Bergen	53 26 N	39 45 W	Sept. 24	5 p., 24	Sept. 25	28.94	SW	SW, 4	SW	SW, 8	
ameronia, Br. S. S.	Glasgow	New York	44 40 N	56 37 W	do	6:15 a., 25	Sept. 26	29.13	SSE	SSE, 7	W	WSW, 9	SSE-W.
la, Am. S. S.	Antwerp	Baltimore	49 44 N	38 00 W	Sept. 25	10:30 a., 26	Sept. 27	29.74	S	WSW, 7	W	SW, 9	S-SW-S.
ollamer, Am. S. S.	Bordeaux	New York	47 02 N	50 05 W	do	3 a., 26	Sept. 26	29.48	SW	WSW, 8	W	W, 9	WSW-W.
ity of Alton, Am. S. S.	New York	Rotterdam	42 48 N	59 30 W	do	—, 25	do	29.43	WNW	WNW, 7	W	W, 8	Steady.
ina, Br. Tk. S. S.	Port Arthur	Montreal	48 50 N	63 54 W	do	—, 25	Sept. 25	29.14	NW	WNW, 10	NW	NW, 10	Do.
old Harbor, Am. S. S.	Boston	Manchester, England.	49 12 N	43 48 W	Sept. 26	9 a., 26	Sept. 27	29.64	S	SW, 8	WSW	SW, —	S-SW.
eorge H. Jones, Am. S. S.	Las Piedras	New York	14 49 N	71 50 W	Sept. 7	11 p., 7	Sept. 8	29.60	S	S, 8	SE	S, 8	WSW-S.
alamares, Am. S. S.	Habana	Cristobal	17 08 N	82 04 W	Sept. 9	5 p., 9	Sept. 9	29.67	E	E, 7	SSE	SE, 8	E-SE.
legria, Hond. S. S.	Philadelphia	Port Antonio, Jamaica.	18 12 N	77 02 W	Sept. 12	2 p., 12	Sept. 12	29.72	NE	SSE, 11	SSW	SSE, 11	NE-SE.
artago, Am. S. S.	New Orleans	Puerto Barrios	19 25 N	85 50 W	Sept. 13	4 a., 14	Sept. 14	29.68	ENE	ENE, 7	SE	SE, 7	ENE-SE.

Ocean gales and storms, September, 1931—Continued

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
NORTH PACIFIC OCEAN			° ′	° ′				Inches					
Victoria, Am. S. S.	Seattle	Nome	50 50 N	134 05 W	Sept. 4	Noon, 4	Sept. 5	29.34	SE	SSW	W	SSW, 9	SW-W.
Siamese Prince, Br. M.S.	Los Angeles	Shanghai	34 44 N	172 20 E	do	7 a., 5	do	[1]29.89	SW	SSW, 8	NW	NW, 8	SW-W-NW.
Do	do	do	34 54 N	153 56 E	Sept. 7	11 p., 7	Sept. 8	[1]30.00	SW	do	NW	SSW, 8	WSW-NW.
Chief Capilauo, Br. S. S.	Takctoyo	Vancouver	34 41 N	139 42 E	Sept. 9	Noon, 10	Sept. 11	29.65	NE	N, 7	NNW	N, 8	N-NNW.
San Luis Maru, Jap. M. S.	Elwood	Yokobama	34 00 N	155 50 E	Sept. 11	2 a., 13	Sept. 13	[1]29.42	SSW	ESE, 6	N	SE, 8	SE-ESE-E.
Courageous, Am. M. S.	Shangbai	San Pedro	39 34 N	138 44 E	Sept. 12	2 p., 12	Sept. 12	29.16	SE	SE, 12	SE	SSE, 12	SE-SW.
Kurohime Maru, Jap. S. S.	Osaka	Portland	48 51 N	178 28 E	Sept. 18	1 p., 18	Sept. 18	29.38	WSW	W, 8	W	W, 8	WSW-W.
Do	do	do	49 20 N	166 16 W	Sept. 19	11 a., 20	Sept. 20	28.40	N	NNW, 12	WSW	NNW, 12	N-NW.
Olympia, Am. S. S.	Cebu, P. I.	Los Angcles	40 16 N	168 30 W	do	3 p., 19	do	[1]29.12	NE	N., 9	W	WNW, 12	NNW-WNW.
Courageous, Am. M. S	Shanghai	San Pedro	47 30 N	158 25 W	do	10 a., 20	do	29.36	NE	SSW., 10	SW	SSW, 10	SSW-S.
Kiyo Maru, Jap. S. S.	Sado Is	Los Angeles	46 05 N	154 30 W	do	4 a., 20	do	29.74	SSE	SE, 7	SW	SSE, 9	SSE-S.
Somedono Maru, Jap. S. S.	Miike	Port Angeles	49 32 N	171 00 W	Sept. 20	2 p., 20	do	29.54	N	NW, 8	NW	NW, 8	N-NW.
City of Vancouver, Can. S. S.	Osaka	Prince Rupert.	44 59 N	162 40 E	Sept. 21	8 p., 22	Sept. 23	29.65	W	W., 7	WNW	W, 8	Steady.
Granville, Pan. M. S.	Hong Kong	San Pedro	22 25 N	121 55 E	Sept. 23	4 a., 24	Sept. 24	29.62	SW	SSE, 8	S	S, 9	SW-S.
Asuka Maru, Jap. M. S.	Yokobama	San Francisco	36 36 N	143 54 E	Sept. 26	6 p., 27	Sept. 28	[1]29.64	SE	SE, 9	SSE	SE, 9	
Shoyo Maru, Jap. S. S.	do	do	47 45 N	163 30 W	Sept. 27	8 p., 28	Sept. 30	[1]29.41	SW	W	WNW	NW, 9	W-NW.
Hakubasan Maru, Jap. M. S.	do	do	48 02 N	164 24 W	do	do	do	29.54	S	WNW		NW, 9	
Victoria, Am. S. S.	Nome	Seattle	53 50 N	149 05 W	Sept. 29	4 a., 29	do	28.66	N	WNW	WSW	WSW, 9	
Yukon, Am. S. S.	Seattle	Seward	58 26 N	138 00 W	Sept. 30	2 a., 30	do	28.74	NE	NE, 8	N	NE, 8	4 points.
MEXICAN WEST COAST STORM REPORTS													
Marian Otis Cbandler, Am. S. S.	Los Angeles	Philadelpbia	16 00 N	98 00 W	Sept. 6	8 p., 6	Sept. 7	29.67	Var	E, 3	ENE	ENE, 8	E-Var.
Sea Tbrush, Am. S. S.	Balboa	San Pedro	20 48 N	108 12 W	Sept. 9	—, 11	Sept. 12	29.45	SE	NE, 8	WSW	NE, 10	ENE-NE.
City of Elwood, Am. M. S.	do	do	21 00 N	107 52 W	Sept. 10	do	do	29.60	ESE	S, 8	SW	SSE, 8	S-SSE.
Astrouomer, Br. S. S.	Los Angcles	Balboa	20 35 N	107 26 W	Sept. 11	5 a., 11	do	28.73	SE	SE	SSW	SxW, 10	SE-S-SSW.
San Rapbael, Am. S. S.	Philadelpbia	San Pedro	22 00 N	108 58 W	do	4 a., 12	do	29.53	SE	SW, 9	S	SW, 9	SSW-SW.
Chattanooga City, Am. S. S.	Balboa	do	20 27 N	107 35 W	do	—, 12	do	29.63	SE	SE, 7	SSW	SSE, 8	SE-SW.
W. S. Miller, Am. S. S.	Mazatlan	Cape San Lucas.	23 00 N	107 00 W [2]	do	9 p., 11	do	29.40	SSE	SE, 12	SW	SE, 12	Steady.
Malayan Prince, Br. S. S.	Colon	Los Angeles	15 30 N	101 30 W [2]	Sept. 13	4 p., 14	Sept. 14	29.58	WSW	WSW, 9	W	WSW, 9	
San Felipe, Am. S. S.	San Pedro	Balboa	17 45 N	103 25 W	Sept. 14	do	do	29.54	SE	E, 4	SW	E, 8	SE-E.
Willboro, Am. S. S.	Balboa	San Diego	18 11 N	104 01 W	Sept. 15	6 a., 15	Sept. 15	29.60	SE	SE, 7	SE	SE, 10	Steady.
Piave, It. S. S.	Colon	Los Angeles	20 00 N	106 00 W	Sept. 17	3 a., 17	Sept. 19		NW	NW, 6	NNW	—, 8	
Seminole, Br. M. S.	Panama	San Pedro	17 43 N	103 19 W	Sept. 20	4 p., 20	Sept. 20	29.64	ESE	E, 7	E	E, 8	ESE-E.
American Star, Am. S. S.	San Francisco	Canal Zone	18 00 N	104 00 W [2]	do	do	do	29.61	ESE		ESE	ESE, 9	
Ohioan, Am. S. S.	Los Angcles	New York	18 48 N	104 17 W	Sept. 21	4 a., 21	do	29.69	E	ExS, 8	ExS	ExS, 8	Steady.
Suriname, Am. S. S.	San Francisco	Cristobal	19 40 N	105 45 W	do	10 p., 21	Sept. 22	29.67	NE	ESE, 8	SE	ESE, 9	E-ESE.
New Jersey, Am. S. S.	San Pedro	New York	21 31 N	108 26 W	Sept. 22	8 p., 22	do	29.49	E	E, 7	SSE	SE, 9	
Thos. H. Wheeler, Am. S. S.	Balboa	San Pedro	22 09 N	109 18 W	do	7 p., 22	Sept. 23	29.35	E	E, 8	SSE	E, 8	E-ESE.
Arizonan, Am. S. S.	San Francisco	New York	23 00 N	110 00 W [2]	do	4 a., 23	do	29.72	E	ESE, 8	S	SE, 9	E-ESE.
Dorothy Luekenbach, Am. S. S.	New York	San Pedro	21 46 N	108 59 W	do	4 p., 22	do	29.47	SE	SE, 9	N	SE, 9	Steady.
Robin Hood, Am. S. S.	Longview	Balboa	25 00 N	113 00 W [2]	Sept. 23	3 a., 24	Sept. 24	29.75	NE	SE, 7	SSE	E, 9	
Willkeno, Am. S. S.	Los Angeles	Charleston	18 42 N	105 06 W	Sept. 27	5 a., 27	Sept. 27	29.60	NNE	E, 9	SE	ESE, 10	ENE-E.
Vega, Am. S. S.	San Diego	Balboa	18 45 N	104 40 W	do	4 a., 27	do	29.68	E	E, 7	SE	ExS, 8	E-ESE.
Chas. R. McCormack, Am. S. S.	San Pedro	do	18 52 N	105 49 W	do	Noon, 27	Sept. 28	29.13	NNE	ESE, 12	SE	ESE, 12	E-ESE.
Minnesotan, Am. S. S.	Los Angeles	New York	20 15 N	108 47 W	do	6 p., 27	do	29.76	ESE	ESE, 7	SE	ESE, 8	ESE-SE.

[1] Barometer uncorrected.

[2] Position approximate.

NORTH PACIFIC OCEAN

By Willis E. Hurd

Atmospheric pressure.—With the coming of early autumn atmospheric pressure began to lessen over the upper waters of the North Pacific Ocean. Depressions became more frequent, and as they concentrated principally over the peninsula and neighboring Gulf of Alaska, it was here that the average center of the Aleutian Low appeared during September. Pressures for the entire region, however, were above the normal for the month, as they were also in July and August.

The North Pacific anticyclone, while more restricted in area on the average than in August, remained for the most part well developed off the middle American coast and thence westward to about longitude 170° W. At Midway Island, however, as well as at coast stations of the United States, pressures were below normal.

Frequent cyclones and anticyclones appeared to the westward of longitude 160° E., but the average pressure was comparatively low in Asiatic waters south of the fortieth parallel, increasing thence northward for some distance.

The following table gives the barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, September, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	29.96	+0.06	30.34	13th	29.64	30th.
Dutch Harbor [1]	29.89	+0.13	30.44	26th	29.10	21st.
St. Paul [1, 2]	29.87	+0.16	30.42	26th	29.36	16th.
Kodiak [1, 3]	29.77	+0.06	30.22	23d	29.18	29th.
Midway Island [1]	29.93	−0.08	30.12	30th	29.76	11th.[3]
Honolulu [4]	29.99	−0.01	30.16	27th	29.86	3d.
Juneau [4]	29.86	−0.06	30.60	21st	29.00	29th.
Tatoosh Island [4, 5]	29.98	−0.03	30.31	22d	29.57	18th.
San Francisco [4, 5]	29.93	−0.01	30.11	29th	29.67	22d.
San Diego [4, 5]	29.86	−0.03	29.99	3d	29.71	11th.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] And on other dates.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—During the early half of September comparatively quiet summer conditions prevailed along the upper trans-Pacific steamship routes, gales occurring only infrequently and over small areas. But from the 18th until the end of the month there was a sharp increase in the frequency and general severity of gales and an expansion of the areas of storminess.

The principal extratropical cyclone of the month seems to have originated near and to the northward of Midway Island about the 18th. It was first known as a severe storm on the afternoon of the 19th when the American steamer *Olympia* encountered it in gales of strong to hurricane force near 40° N., 168° W. The cyclone by this time was moving rapidly northward. On the 20th at 11 a. m. local time, the Japanese steamship *Kurohime Maru* experienced it as a northerly to westerly gale of hurricane force, lowest barometer 28.40 inches, near 49° N., 166° W. Earlier in the day southwesterly gales of force 11 were reported by another vessel from about 42° N., 162° W. On this date of the storm's greatest severity and widespread prevalence gales equaling or exceeding force 9 covered a region bounded roughly by longitudes 150° and 170° W., latitudes 40° to 52° N. The cyclone center, losing energy, passed east of Dutch Harbor, where the barometer fell to 29.10 inches on the morning of the 21st and by the 22d had entered the Arctic Ocean north of Alaska.

An eastward-moving low of less intensity from Siberia entered the Sea of Okhotsk on the 20th. After leaving the Kuril Islands it caused fresh to strong gales to the eastward on the 20th to 22d. On the 23d it crossed the central Aleutians into the Bering Sea, and by the 25th had overspread the Gulf of Alaska, where it remained with fluctuating intensity until the close of the month. Some eastbound steamships on the northern routes between the 22d and 30th remained under the influence of this disturbance for several days harassed by frequent fresh to strong gales.

South of latitude 40° gales, so far as reported, were infrequent and of moderate to fresh force only, except those due to disturbances of the Tropics.

Tropical cyclones—Typhoons.—In addition to a very small but violent typhoon off the southeast China coast, a description of which by the Rev. Miguel Selga, director of the Philippine Weather Bureau, appears elsewhere in this issue of the Monthly Weather Review, at least three other typhoons occurred in September, two of which our own reports show to have been of great violence. Two of these cyclones originated in low latitudes east of the Philippines. One, forming early in the month, moved northward between the Nansei Islands and the mainland of China on the 9th and 10th. By the 11th it had acquired considerable energy south of Chosen, and on the 12th in the Japan Sea the report of the American motor ship *Courageous* indicates that it was by then, at least, of hurricane intensity. The storm crossed the northern island (Yezo) of Japan and on the 13th lay over the Sea of Okhotsk.

The other low-latitude storm crossed the Philippines between the 19th and 21st, and Taiwan on the 22d and 23d. It skirted the west coast of the Japanese Archipelago between the 25th and 28th and went northward into Siberia west of Sakhalin Island.

The third typhoon was apparently the most severe. It first appeared as a low west of the Ogasowara Islands on the 7th. It proceeded northeastward and when central some 200 miles east-southeast of Yokohama, or near latitude 33° 39′ N., 142° 56′ E., at 4:30 p. m. of the 10th, according to the special report of the American steamship *Patrick Henry* (R. A. Smith, second officer and observer) was of hurricane force from southeast by south. The position of the vessel was practically stationary for several hours. Light winds occurred at the vessel from 9:30 to 10 p. m. The lowest barometer, 28.20 inches (uncorrected), was read at 10 p. m. "at the end of the southerly winds." The wind was of hurricane force from 4:30 p. m. until midnight, except for the comparative calm at the vortex, but was of greatest violence after the shift to west. The typhoon continued on a northeasterly course until the 12th, when it was lost to observation near 40° N., 160° E.

Mexican west coast cyclones.—At least three cyclones with winds of force 11 to 12 occurred in these waters in September; in addition to one other instance in which winds of whole gale force were encountered by several ships in positions strongly indicating a tropical storm development and movement. These storms are discussed in considerable detail in another section of this Review, where they are considered chronologically with associated storms moving into Mexico from the Caribbean area. A brief summary of the movements in the Pacific which were all quite regularly northwestward, closely paralleling the Mexican west coast, is presented here as a part of the record of month's weather over the Pacific.

The first storm, which caused the loss of the American steamship *Colombia* on the 12th, and took a number of lives in the Mexican town of Santa Rosalia on the 13th, was first in evidence as a moderate cyclonic storm about latitude 15° N., longitude 100° W., on the 6th and 7th. It ceased to be a damaging storm after reaching the upper part of the Gulf of California on the 14th, on which date another disturbance was developing in approximately the same location where the first had originated a week before. This second storm was of only moderate violence, and, after following a course almost like its predecessor into the mouth of the Gulf of California, disappeared by the 18th. The third and fourth storms developed somewhat farther from the coast about 12° N., 102° W., the earlier on the 20th, and the last on the 26th. The movement of the first after the 20th was somewhat problematical, but it appears however to have traveled about due northwestward causing gales in the vicinity of

25° N., 115° W., on the 24th, after which it seems to have diminished and disappeared. The last storm, beginning on the 26th, moved more northward, and, like the first two of the month, entered the Gulf of California and disappeared after the 29th.

Winds at Honolulu.—The prevailing wind direction at Honolulu continued from the east, with the maximum velocity of 25 miles an hour from the east on the 25th.

Fog.—The occurrence of fog on the north Pacific lessened appreciably in September along the northern routes, and was reported on only 1 to 4 days in any 5° square. The region of most frequent occurrence lay along the American coast between 30° and 50° N., with about 30 per cent of the days with fog between Point Conception and the mouth of the Columbia River.

The Moyle-Allen airplane flight over the northwestern Pacific.—On September 8, Don Moyle and Cecil A. Allen, of California, took off from Sabishiro Beach, Japan, 375 miles north of Tokyo, attempting a nonstop flight of 4,465 miles to Seattle. They were thereafter lost until it was learned 10 days later that they had been forced down by stormy weather, landing upon a remote island of the western Aleutians. After seven days, they hopped off for Siberia, landing on the 17th on the Kamchatka coast, 1,900 miles north-northeast of their starting point of the 8th. They later flew to Nome.

THE SILVERSANDAL TYPHOON, SEPTEMBER 1 TO 4, 1931

Abridged from a report submitted by Rev. MIGUEL SELGA, S. J., director of the Manila Weather Bureau

To pass from a gentle breeze into a whole gale in the short interval of two hours without any apparent sign of a brewing storm was the unusual experience on September 1, 1931, of the 3,693-ton motor ship *Silversandal*, of the Silver Line. In its voyage from Shanghai to Manila the motor ship encountered gentle easterly breezes down the China coast and the Formosa Channel on the last day of August and the early morning of the 1st day of September, with the barometer remaining stationary at 755.8 mm. for eight hours. The usual precursors of a typhoon, such as convergence of cirri, shifts of the wind, or unusual swell, were all absent. No typhoon warning had been issued by the near-by broadcasting stations of Pratas and Keelung.

According to the log book, at 4 a. m. on September 1, when the *Silversandal* was approaching the northern entrance of the Formosa Channel, a gentle breeze was blowing from the northeast. The weather was noted down as fine and clear by the officer of the deck. At 8 a. m. the wind had increased one point in force and shifted to east by north, while short-lived rain squalls gave indications of unsettled weather. Two hours later the storm was on and the wind had increased to gale force. At 10:50 a. m. the wind was blowing whole gale and the speed of the ship had to be reduced. The barometer dropped to 744.5 mm. at 11:30, with the wind from east by north, of hurricane force. The blast of the whistle of the ship was lost in the roar of the wind and could not be heard by the members of the crew. The rain was blinding and the visibility so low that one end of the ship could not be seen from the other. At noon the wind was from the east and had dropped from force 12 to force 10, and by 4 p. m. the wind had veered to south-southeast and decreased to force 5 while the barometer had risen to 752.3 with general improvement of weather conditions.

This typhoon must have originated west of southern Formosa and passed north of Pratas in its westward motion without affecting considerably the barometers of western Formosa and of Pratas. No definite information on the origin and violence of the storm could be secured until the *Silversandal* made the port of Manila and the officers and log book of the ship were consulted.

The disturbance moved westward unnoticed throughout the evening and night of September 1, but at 6 a. m. on September 2, there were evident signs of a typhoon approaching Hong Kong from the southeast. About noon the gale developed with surprising suddenness in the British colony and many native craft were caught unawares.

Two unusual features characterized the passage of this typhoon close to Hong Kong—the unsteadiness of the winds and the oscillations of pressure. The wind vane of Hong Kong Observatory is reported as having made five complete revolutions between 8 and 11 p. m. In the words of the director of the royal observatory, the barometer trace was the most remarkable ever recorded at the observatory, the pen oscillating rapidly to the extent of a tenth of an inch between 8 and 9 p. m. Lowest pressure was 739.9 mm. at 2:55 p. m., attended by wind rising to a velocity of 124 kilometers per hour in the maximum gust, but some hours later the wind rose suddenly again to high velocities between 8 and 10 p. m., reaching a maximum velocity of 151 kilometers per hour in a gust at 9 p. m.

The mean speed of progression of the typhoon from the west of southern Formosa to the Asiatic Continent was about 8.6 miles per hour. The weather maps of September 4 show the center of the typhoon filling up over Kwangsi Province.

TROPICAL STORMS OF SEPTEMBER, 1931, IN NORTH AMERICAN WATERS

By W. F. McDONALD

September was marked in American tropical waters by no less than seven storms. At least three of these storms reached full hurricane intensity, one of them becoming a major disaster. Tracks of three storms which moved across the Caribbean Sea are illustrated elsewhere in this issue, in connection with a special report on hurricane damage in Porto Rico, the only United States possession to suffer by a hurricane during the month.

The first cyclonic development of the month began north of the Virgin Islands on the 1st, and was of minor intensity. It moved westward during the next six days reaching the western end of Cuba where it recurved northeastward on the 7th. The only gales reported during the progress of this relatively mild disturbance were over Mona Passage on the 2d, but flooding rains which caused great damage and some loss of life in Porto Rico may be attributed to conditions attending this cyclone.

While the first disturbance was in progress, another was developing in the southeastern Caribbean Sea. It was first suspected not far from Barbados on the 6th. The third for the month was also arising almost simultaneously in the Pacific a short distance southeastward from Acapulco, Mexico, where the American steamship *Marian Otis Chandler* encountered a cyclonic gale on the 6th. Both of these disturbances developed into storms of relatively small diameter but of full hurricane intensity as they progressed during the succeeding week.

While these two hurricanes were in simultaneous progress, and approaching the peak of their intensity, the

fourth tropical storm of the month was getting under way over the northern portion of the Leeward Islands on the 9th, and this storm likewise developed full hurricane intensity in its life of approximately a week as it moved westward to lose itself finally over the highlands of central Mexico.

It is of considerable interest, and perhaps of some importance for future studies of hurricanes, to point out that the three storms just mentioned, all of which reached the intensity of severe hurricanes, appear to have developed full severity at about the same time. The first storm ravaged Belize, British Honduras, on the afternoon of September 10, but ships encountering it earlier did not find winds of hurricane force. The second was first encountered as a hurricane of force 12 in the entrance to the Gulf of California on the 11th, and the third passed San Juan with damaging severity about midnight of the 10th–11th. The first two of these storms were in existence for four or five days however, before they reached hurricane intensity, but the third appears to have developed its strength within 36 hours from the time when its presence was first suspected, although it is possible that this storm may have originated still earlier in the little-traveled regions northeast of the Leeward Islands.

That three widely separated storm movements should thus show almost simultaneous increase in intensity may, of course, be pure coincidence, but it is not outside the bounds of probability that some major influence was at work in the weather conditions over the 2,000-mile arc embraced by the equally spaced locations of storms over Porto Rico, the Gulf of Honduras, and the entrance to the Gulf of California. The fact is at least worth recording for possible future reference.

The history of these three hurricanes will now be discussed in some detail, taking each in its chronological order by date of origin. As stated above, the Belize hurricane appears to have originated over the Windward Islands about the 6th of the month. The first ship's report, establishing conclusively its nature as a pronounced cyclonic depression, comes from the American tanker *Geo. H. Jones* (Captain Cavileer) near latitude 15° N., longitude 70° W., about midnight of the 7th–8th, with the barometer dropping sharply from 29.8 to 29.6, and a gale of force 8. The progress of this disturbance continued steadily west-northwestward during the next two days, with a number of ships reporting barometric decreases and winds at times reaching force 10 to 11, but none experiencing conditions of full hurricane intensity, even on the morning of the 10th in the Gulf of Honduras, where shipping is relatively numerous.

The 10th of September is a festival date in Belize, British Honduras, and the populace was out in holiday mood on the afternoon of that day as the hurricane, still of small extent but of ferocious intensity, moved in upon the town. It raged throughout much of the afternoon, reaching hurricane velocity about 1 p. m., and the center of the storm appears to have passed Belize about 3:30 p. m. Some details, excerpted from a report made by D. A. Fairweather, Government wireless operator at Belize, follow:

> The wind began to increase about 11 o'clock from the northeast and by 12:40 p. m. had reached a velocity of 48 miles an hour.
>
> At 1:15 p. m. the velocity was 60 miles and the barometer registered 28.10. Between 1:35 and 2:00 p. m. the wind lulled to 38–48 miles returning to 60 miles an hour at 2:05 p. m. from the north. It crept up to 72 miles an hour at 2:15 p. m., 96 miles at 2:30 p. m., 120 miles at 2:45 p. m. and maintained a velocity of 132 miles an hour from 2:50 to 3 p. m. At 3:05 p. m. the wind dropped to 72 miles and finally to about 12 miles.
>
> At 3:44 p. m. the wind shifted to the southwest and rose suddently to 80 miles an hour. The anemometer gave way at this juncture.

The winds swept the sea forward over the environs of the port, which is built on exceedingly low ground, choked the mouth of the Belize River with the wreckage of small boats, including six Honduran schooners, piled a 200-ton dredge upon the wharf, and with wreckage as battering rams, smashed into the structures of the town itself. It was a disaster of major proportions, entailing a loss of life that is not definitely known, but probably exceeding 1,500 souls, and a property loss that was estimated in later dispatches at $7,500,000.

Meanwhile, the third storm of the month was raging as a hurricane over the Gulf of California. As noted above, this storm probably began on the 6th, and was first reported by the American steamer *Marian Otis Chandler*, Captain Sawyer, which encountered a variable to east-northeast gale of force 8, with a lowest barometer of 29.67 inches, in latitude 16° N., longitude 98° W. If so, however, there is a gap in the storm history, owing to lack of reports, for it next appears on the afternoon of the 9th, when, at 8 p. m., the Dutch motorship *Drechdijk* encountered an east-southeast gale of force 8 near 19° 30′ N., 105° 35′ W., followed by conditions which indicated that the disturbance was passing to the northwestward.

A maximum wind of force 10, prior to the regular a. m. observation at the Mexican weather station at Manzanillo, with barometer reading 29.68 inches, marked the position of the disturbance to westward of that station on the morning of the 10th. On the morning of the 11th the British steamer *Astronomer* encountered the storm about 20° 30′ N. and 107° 30′ W. The further progress of the hurricane appears in the report of the American steamship *W. S. Miller*, which experienced a southeast hurricane near 23° N. and 108° W., and barometer down to 29.4 inches, at 9 p. m. of the same date. This was the first report to show that the storm had developed full hurricane intensity.

Late on the afternoon of the 11th the French steamer *Korrigan III*, lying in port at La Paz, Lower California, experienced the preliminary northeast gales of the approaching hurricane. The report of the first officer R. Moya of the *Korrigan III*, Capt. S. Meza, furnished to Mr. E. W. Easton, American vice consul at Mazatlan, Sinaloa, gives definite information as to the severity of the storm in this vicinity. By 2 a. m. of the 12th the wind in the harbor of La Paz was blowing with force 12 from the north, and the pressure was falling. At 3 a. m. the reading of the barometer on the *Korrigan III* reached 28.74 inches, followed for some minutes by greatly diminished wind. At 3:35 a. m. the wind came from the south and soon rose to force 10, as the hurricane center passed.

There was no great damage in La Paz as the hurricane passed, but with its further movement up the peninsula of Lower California, on the morning of September 12 it caused the American steamship *Colombia* to go aground on Santa Margarita Island as she became involved in the winds and possibly the unusual currents attending the hurricane's progress. This ship, a passenger liner en route from New York to San Francisco, carried 234 passengers and crew, all of whom were safely removed through able seamanship of the officers of the stranded vessel and the rescuing ship *San Mateo*, of the United Fruit Line. There was hope at first that the ship might be salvaged, but continued heavy weather prevented, and the vessel, abandoned on the 13th, broke up under stress of the seas developed during the following week by

the succeeding storm movement. More than $150,000 in gold and silver, carried by the *Colombia*, was later recovered, but the remainder of the cargo, including personal belongings of the passengers, seems to have been a total loss.

As the hurricane moved farther northward it was reported in press dispatches to have caused exceedingly high tides on the 13th at Guaymas and Santa Rosalia, Mexico, with approximately 50 lives lost by drowning in the 9-foot inundation of the latter town. From this point the storm seems to have diminished and dissipated, probably moving inland over the State of Sonora.

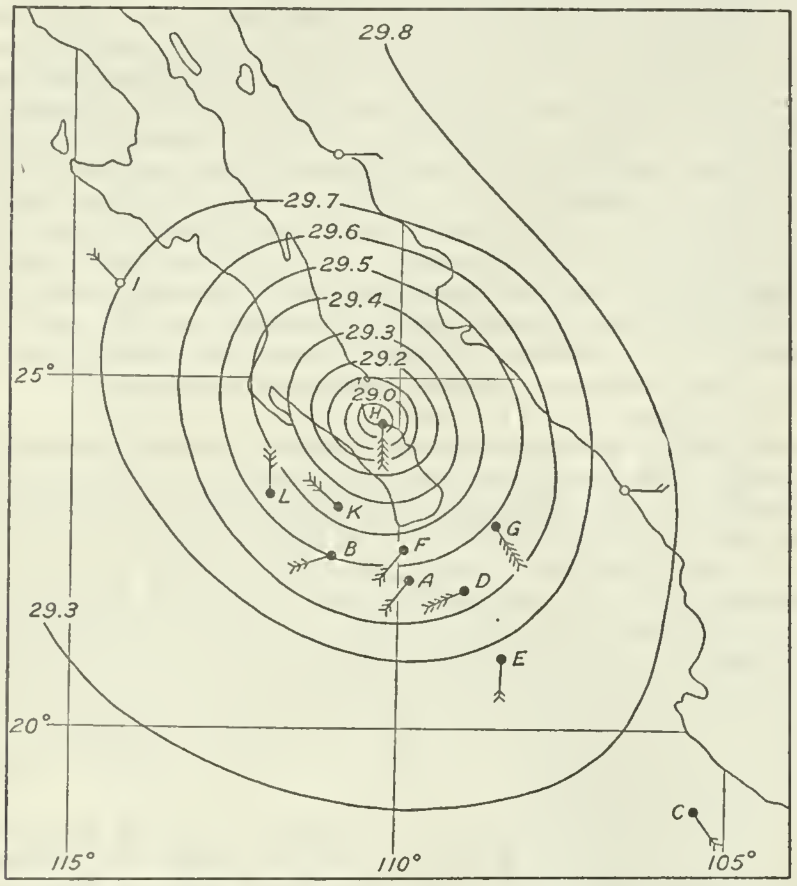

FIGURE 1.—Observations from vessels and near-by coast stations in the hurricane of Sept. 12, 1931, at Greenwich noon. Storm center just west of La Paz. Letters signify the following vessels: *A*, American steamer City of Elwood; *B*, American steamer Sea Thrush; *C*, British steamer Astronomer; *D*, American steamer San Raphael; *E*, American steamer Chattanooga City; *F*, American steamer Muntropic; *G*, American steamer W. S. Miller (position approxmate); H, French steamer Korrigan III (4 a. m. in port at La Paz); *I*, American steamer President Van Buren; *K*, American steamer San Felice; *L*, American steamer Nebraska.

The wind and barometer conditions reported from several vessels caught in this storm on the early morning of September 12 (about Greenwich noon) are charted in Figure 1 to indicate the location and intensity of the hurricane at that time.

The fourth of the seven storms originating in September, first reported over the waters north of the Leeward Islands on the 9th, passed Porto Rico as a small but well-developed hurricane on the night of the 10th–11th. A report of its movement along the north coast of Porto Rico and of its characteristics at that time will be found elsewhere in this issue. The next definite report of its progress is from the Honduran steamship *Alegria*, which was in harbor at Port Antonio, Jamaica, on the 12th, and experienced typical hurricane conditions with wind shifting from northeast to southeast and of force 8 to 11 during that afternoon, but without extreme depression of the barometer.

Only one further gale report is at hand for this storm as it continued to travel due westward across the Caribbean Sea, namely that from the American steamship *Cartago* which reported a moderate gale, shifting from east-northeast to southeast, in 19° 25′ N., 85° 50′ W., early on the 14th. After this date the disturbance moved on across Yucatan and evidently into the lower Gulf of Campeche, finally passing inland over or near the city of Vera Cruz at 4 a. m. of September 16.

A special report received from Ing. Ernisto Dominguez, in charge of the meteorological observatory at Vera Cruz, gives the following facts: Preliminary evidences of the approach of the hurricane became unmistakable on the 15th, with a moderate northerly wind, increasing without a rise but rather a fall in the barometer. By afternoon the wind became gusty and was sufficiently strong by nightfall to make it necessary to close the port. By midnight the violence of the wind had risen to near hurricane force with the barometer dropping decidedly after 10 p. m., but the direction of the wind continued rather steadily from the north-northwest up to the time of barometric minimum, 29.43 inches, about 4 a. m., at which time there was a shift to east-northeast, indicating that the center of the disturbance moved inland to the south of the observatory.

The clouds were overrunning the surface wind, however, at 2 a. m., being from an easterly direction already at that hour. With the shift of the surface wind to easterly just before 4 a. m., there was an increase in force, and the maximum velocity was attained a little after 5 a. m., when 42.5 m. p. s. (95 m. p. h.) was recorded. The report states that this velocity established a record for Vera Cruz.

There appears to have been no damage of great consequence in the city of Vera Cruz, but news dispatches reported the loss of a number of small ships outside of the harbor, the largest of which was the 800-ton Mexican steamer *Dos Equis*, which sank with all hands lost, including a number of passengers.

This was the third and last storm movement of the month on the Atlantic side of the continent, with but one storm previously occurring on the Pacific coast. Before the Vera Cruz hurricane had crossed Yucatan, however, the second Pacific cyclone and the fifth tropical storm development of the month was in progress.

This cyclone closely followed its predecessor of a week before, appearing near 15° N., 100° W., early on the 14th, but it failed to develop the intensity of the first Pacific storm. At 8 a. m. of the 15th the American steamer *Willboro*, near 18° N., 104° W., met with a southeast gale of force 10, the highest noted for the storm. The lowest barometer reading reported was 29.54 inches, from the American steamer *San Felipe* in 17° 45′ N., 103° 25′ W., at 4 p. m. of the 14th. The last gale reported in connection with the storm was of fresh force and occurred near 20° N., 106° W. on the 17th. Thereafter the disturbance, as indicated by reports, seems to have been of slight force, yet it is quite possible that its accompanying seas were sufficiently rough to cause the final breaking up of the *Colombia* between the 18th and 20th.

The last two developments of the month, both in the Pacific, apparently originated in the same locality, about three or four hundred miles south of Acapulco, Mexico, and moved northwestward, approaching the peninsula of Lower California, to lose themselves finally by passing inland over extreme northwestern Mexico.

The earlier of the two and the sixth tropical disturbance of the month in American waters was first shown by observations on the 20th, when the British motor ship *Seminole* reported a barometer of 29.64 inches and fresh east gale near 17° 43′ N., 103° 19′ W. On the 21st the American steamer *Suriname* had a strong gale from ESE. near 19°

N., 106° W. On the 22d the steamer *New Jersey* had a strong southeast gale near 21° N., 108° W., barometer depressed to 29.49 inches. On the 23d the steamer *Steel Age* had a southeast gale of force 11 near 23° N., 111° W., barometer 29.26 inches. On the 24th the steamer *Robin Hood* had a strong southeast gale near 25° N., 113° W. Thus, was shown the northwestward progress for five days of a storm that was at least of near-hurricane force off the west coast of Lower California.

The seventh cyclone was first indicated by reports as organizing on the 26th in the vicinity of 17° N., 103° W. It probably attained the height of its energy on the 27th, during which day the steamship *Willkeno* had a whole gale from ESE., barometer 29.60, near 19° N., 105° W., and the steamer *Charles R. McCormack* encountered strong northeast to southeast gales near 19° N. 106° W., with a maximum force of 12 from ESE. at noon, lowest pressure 29.13 inches. Captain Christensen of this vessel said the storm was accompanied by the heaviest precipitation of his experience. The storm proceeded northwestward with apparently lessening energy and was last heard from in connection with a moderate easterly gale on the 29th at about 23° N., 110° W.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

Table 1 shows the average temperatures for the Caribbean Sea and the Straits of Florida for September of each year from 1919 to 1930, inclusive, and Table 2 summarizes the temperatures for September, 1930, in the same areas. The chart shows the number of observations taken in September, 1930, within each 1° square and mean temperature data for subdivisions of the area considered.

September is the warmest month in the Caribbean Sea, with the mean yearly peak in temperature occurring at approximately the end of the month. The Straits of Florida, while usually cooler in September than in August, are warmer than in July, and the temperatures there drop out slowly until the final days of the month, when the abrupt autumn drop in temperature ordinarily commences.

The last quarter of September, 1930, was slightly cooler than the 11-year mean in the Caribbean, but the month as a whole was warmer than the average, the seventh consecutive month of high temperatures. The Straits were close to the seasonal average in temperature, except in the final quarter, when they were above the mean.

TABLE 1.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for September, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean (°F.)	Number of observations	Mean (°F.)
1919 [1]	87	82.6	28	82.2
1920	192	82.2	35	83.3
1921	255	82.1	104	83.4
1922	150	82.2	66	83.0
1923	237	82.0	71	83.1
1924	310	83.4	79	83.7
1925	384	82.7	131	83.6
1926	429	83.3	149	83.5
1927	547	83.6	180	84.3
1928	597	82.9	156	83.6
1929	644	82.5	176	82.8
1930	588	83.0	175	83.5
Mean (1920–1930)		82.7		83.4

[1] Not used in computations because of insufficient data available.

TABLE 2.—*Mean sea-surface temperatures (° F.) and number of observations, September, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
First	Sept. 1–7	141	83.1			38	83.5		
Second	Sept. 8–15	169	82.9			51	83.4		
Third	Sept 16–22	137	83.2			35	83.6		
Fourth	Sept. 23–30	141	82.6			51	83.5		
	Month	588	83.0	+0.3	+0.5	175	83.5	+0.1	−0.8

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1931

[For description of tables and charts, see REVIEW, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.7	+4.2	Wetumpka	106	7	2 stations	42	[1] 28	1.23	−2.15	Samson	4.00	2 stations	T.
Arizona	74.7	+0.9	Gila Bend	115	[1] 11	do	23	[1] 20	1.64	+0.38	Henry's Camp	7.04	Granite Reef Dam	0.00
Arkansas	78.4	+4.2	3 stations	102	[1] 15	do	34	[1] 27	1.00	−2.36	Whitecliffs	4.32	Magnolia	0.00
California	65.7	−1.6	Brawley	114	7	Twin Lakes	17	[1] 9	0.18	−0.36	Cuyamaca	2.09	59 stations	0.00
Colorado	61.8	+4.0	Lamar	105	6	Telluride	9	25	1.46	+0.02	2 stations	4.73	Eads	0.00
Florida	80.3	+0.9	Bonifay	102	19	Vernon	47	29	5.32	−1.46	Miami	19.70	Raiford	0.01
Georgia	78.6	+3.2	Millen	107	18	Clayton	35	30	1.31	−2.43	Quitman	4.98	Hazelhurst	0.27
Idaho	57.7	+0.7	2 stations	104	3	Obsidian	18	22	0.98	−0.07	Coolin	2.85	Mountainhome	0.09
Illinois	73.1	+5.8	Sparta	103	17	Mount Carroll	36	28	4.77	+1.03	Paris	9.54	Cairo	1.19
Indiana	71.8	+4.8	Edwardsport	102	10	Delphi	34	29	4.75	+1.51	Terre Haute	9.64	Fort Wayne	2.08
Iowa	71.0	+6.7	Washta	105	7	4 stations	35	[1] 24	6.69	+3.02	Fort Dodge	12.68	Akron	2.68
Kansas	77.5	+8.2	2 stations	111	5	Atwood	31	26	2.50	−0.36	Emmett	9.35	Ness City	0.11
Kentucky	75.1	+4.7	Hopkinsville	103	18	2 stations	36	29	2.74	−0.09	Uniontown	5.94	Burnside	1.22
Louisiana	80.6	+2.7	Dodson	105	[1] 4	Robeline	39	29	1.88	−2.13	Donaldsonville	5.08	Logansport	0.00
Maryland-Delaware	72.2	+4.4	College Park, Md	100	22	Grantsville, Md	30	29	2.54	−0.68	Oakland, Md	5.32	Aberdeen, Md	0.83
Michigan	65.8	+5.7	East Tawas	101	11	3 stations	29	28	5.06	+1.73	Mackinac Island	10.75	South Haven	1.94
Minnesota	64.9	+6.7	Beardsley	111	11	2 stations	26	[1] 24	2.55	−0.48	Grand Meadow	7.34	Wheaton	0.62
Mississippi	79.7	+3.9	Columbus	103	24	do	41	29	0.78	−2.25	Laurel	3.84	5 stations	0.00
Missouri	75.0	+6.0	2 stations	104	[1] 5	3 stations	36	[1] 29	4.16	+0.32	King City	10.80	Dean	0.46
Montana	57.2	+1.9	3 stations	101	6	Upper Yaak River	16	23	1.66	+0.40	Babb (near)	3.83	Melstone	0.09
Nebraska	71.0	+7.1	Imperial	110	5	2 stations	30	[1] 22	2.28	+0.13	Falls City	8.50	Sutherland	0.20
Nevada	61.8	−0.8	Clay City	112	3	Zorra Vista Ranch	13	24	0.53	+0.14	Lamoille	1.72	3 stations	0.00
New England	62.7	+2.5	4 stations	97	11	Garfield, Vt	27	30	3.26	−0.31	West Burke, Vt	8.73	Westfield, Mass	0.69
New Jersey	70.5	+5.0	2 stations	100	[1] 11	3 stations	34	29	1.98	−1.54	Sussex	3.15	Runyon	0.86
New Mexico	67.1	+2.9	Nara Visa (near)	103	14	Selsor Ranch	21	25	2.50	+0.93	Winsors Ranch	8.36	2 stations	0.00
New York	65.2	+4.1	2 stations	101	[1] 10	Indian Lake	27	29	3.86	+0.45	High Market	8.26	Cutchogue	1.09
North Carolina	74.1	+3.2	Fayetteville	106	18	Banners Elk	27	29	1.71	−2.27	Tarboro	6.69	Monroe	0.00
North Dakota	61.4	+5.0	3 stations	107	[1] 6	3 stations	27	[1] 17	2.14	+0.49	Park River	4.63	Power	0.35
Ohio	70.3	+4.7	Portsmouth	99	21	2 stations	33	29	4.01	+1.03	Hillsboro	7.61	Dam No. 28, Ohio River.	1.56
Oklahoma	80.9	+7.0	Jefferson	110	5	do	40	[1] 27	1.17	−2.12	Bartlesville	6.78	2 stations	0.00
Oregon	56.8	0.0	Echo	104	3	Blitzen	13	[1] 9	0.99	−0.21	Astoria	5.36	4 stations	T.
Pennsylvania	69.1	+5.0	2 stations	104	[1] 12	2 stations	29	[1] 29	3.15	−0.31	Saltsburg	6.65	Marcus Hook	0.74
South Carolina	77.5	+3.0	do	107	18	Clemson College	40	28	0.98	−3.14	Beaufort (near)	3.27	Newberry	T.
South Dakota	68.1	+7.2	Gannvalley	112	9	2 stations	29	[1] 23	1.42	−0.37	Sioux Falls	4.28	Dumont	0.04
Tennessee	76.4	+5.1	2 stations	103	[1] 18	Crossville	32	29	1.51	−1.56	Tiftonville	3.99	Selmer	0.02
Texas	81.4	+4.0	3 stations	107	[1] 5	2 stations	43	[1] 22	0.68	−2.19	Jefferson	5.69	20 stations	0.00
Utah	62.1	+1.5	St. George	101	[1] 6	Widtsoe	14	19	0.53	−0.52	Monticello	2.14	Leeds	0.00
Virginia	72.8	+4.4	2 stations	101	22	Burkes Garden	30	29	2.46	−0.63	Christchurch	6.17	Martinsville	0.65
Washington	57.9	−0.1	do	102	[1] 2	Stockdill Ranch	21	23	2.85	+1.04	Big Four	16.32	3 stations	0.04
West Virginia	70.0	+4.0	do	102	[1] 12	Bayard	29	29	3.91	+0.87	Rowlesburg	6.70	Dam No. 25, Ohio River.	1.45
Wisconsin	66.0	+6.2	do	103	10	4 stations	29	[1] 24	5.81	+2.11	Manitowoc	11.83	Iron River	2.22
Wyoming	57.3	+2.9	Worland	102	7	Dome Lake	8	23	1.06	−0.21	2 stations	2.70	Lusk	0.10
Alaska (August)	52.9	−0.3	Skagway	85	10	Eagle	22	27	3.74	−0.09	Mount Roberts (a)	20.34	Barrow	0.42
Hawaii	75.1	+0.5	Kaanapali	96	6	Kanalohuluhulu	49	12	10.14	+4.20	Hilo-Manawalopuna Divide.	52.00	Mahukona	0.0[illegible]
Porto Rico	79.3	+0.4	Mayaguez	95	7	Juncos	60	11	12.76	+4.72	Maricao	27.75	Ensenada	5.51

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							64.2	+3.4										80	2.76	−0.4										5.0		
Eastport	76	67	85	29.87	29.95	−0.08	56.0	+0.2	73	11	62	41	19	50	20	53	50	84	3.61	+0.8	15	5,979	nw.	28	nw.	25	8	4	18	6.7	0.0	0.0
Greenville, Me	1,070	6	----	28.81	29.96	------	56.0	------	88	11	65	32	30	47	36	52	----	86	3.93	------	16	4,057	se.	20	------	25	7	10	13	----	0.0	0.0
Portland, Me	103	82	117	29.85	29.97	−.08	63.2	+3.6	95	11	71	45	30	55	31	56	53	76	2.95	−0.2	10	5,521	nw.	26	nw.	24	15	8	7	4.3	0.0	0.0
Concord	289	70	79	29.67	29.97	−.09	62.8	+3.5	94	11	74	33	30	52	37	----	----	----	2.70	−0.8	9	3,215	n.	21	nw.	8	11	11	8	5.0	0.0	0.0
Burlington	403	11	48	29.53	29.96	−.10	62.4	+2.1	95	11	71	36	29	53	31	----	----	----	3.86	+0.4	14	5,827	s.	36	sw.	17	6	10	14	6.3	0.0	0.0
Northfield	876	12	60	------	30.00	−.06	59.5	+3.4	92	11	70	29	29	49	40	----	----	86	3.81	+0.7	14	4,115	s.	23	sw.	6	5	13	12	6.7	0.0	0.0
Boston	125	106	165	29.85	29.98	−.09	66.9	+3.7	95	11	75	46	29	59	33	60	56	73	1.67	−1.5	8	5,145	nw.	27	nw.	24	16	7	7	4.3	0.0	0.0
Nantucket	12	14	90	29.97	29.98	−.10	65.6	+2.8	88	11	72	52	25	60	20	61	58	82	2.84	+0.4	8	10,427	sw.	36	ne.	28	14	7	9	5.1	0.0	0.0
Block Island	26	11	46	29.96	29.99	−.09	66.0	+2.6	84	11	71	50	29	61	15	62	59	80	1.93	−0.7	7	10,332	sw.	39	w.	24	15	8	7	4.1	0.0	0.0
Providence	160	215	251	29.82	29.99	−.08	67.3	+4.1	94	11	77	44	30	58	31	61	58	77	1.37	−1.8	6	7,067	nw.	38	nw.	24	17	5	8	4.0	0.0	0.0
Hartford	159	122	----	29.83	30.00	−.07	67.8	+6.1	95	10	77	42	30	58	30	----	----	----	1.05	−2.4	10	------	sw.	----	------	----	13	9	8	4.4	0.0	0.0
New Haven	106	74	153	29.89	30.00	−.07	69.2	+5.7	95	11	78	45	29	60	29	63	59	76	4.60	+1.1	9	5,466	s.	24	s.	20	14	8	8	4.5	0.0	0.0
Middle Atlantic States							72.2	+5.1										75	2.02	−1.2										4.0		
Albany	97	107	115	29.89	29.99	−.08	67.0	+3.9	98	11	76	42	29	58	32	60	57	77	1.91	−1.2	9	4,370	s.	20	s.	17	16	5	9	4.5	0.0	0.0
Binghamton	871	10	84	29.10	30.02	−.05	67.4	+6.1	96	12	79	38	29	56	39	----	----	----	2.11	−1.0	10	3,269	nw.	20	ne.	15	9	9	12	5.6	0.0	0.0
New York	314	414	454	29.67	30.00	−.08	71.2	+4.4	95	11	79	48	29	64	23	63	59	72	1.15	−2.2	6	9,159	n.	46	nw.	24	14	9	7	4.3	0.0	0.0
Bellefonte	1,050	5	36	28.93	30.03	------	66.9	------	94	12	80	33	29	54	39	61	58	78	2.46	------	9	------	sw.	34	se.	26	9	9	12	5.4	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	−.07	72.1	+6.3	97	11	82	48	29	63	30	63	59	70	3.35	+0.3	7	3,803	w.	35	w.	2	16	6	8	4.2	0.0	0.0
Philadelphia	114	123	367	29.90	30.03	−.05	74.1	+6.1	97	11	82	50	29	66	23	65	61	68	1.60	−1.5	4	8,266	sw.	36	nw.	24	13	10	7	4.0	0.0	0.0
Reading	325	81	98	29.68	30.02	------	72.0	+5.7	99	12	82	46	29	62	33	64	60	72	2.79	−0.4	4	2,889	sw.	31	sw.	2	15	8	7	4.2	0.0	0.0
Scranton	805	72	103	29.18	30.03	−.04	68.4	+5.5	97	12	79	41	29	57	35	62	59	79	2.09	−1.1	9	3,772	sw.	26	nw.	24	13	10	7	4.4	0.0	0.0
Atlantic City	52	37	172	29.96	30.01	−.06	72.3	+5.5	94	11	79	49	29	66	24	66	63	79	2.55	−0.1	5	10,053	sw.	38	s.	20	17	8	5	3.3	0.0	0.0
Cape May	17	13	49	------	------	------	72.4	+3.4	93	11	80	48	29	65	25	67	65	81	3.13	+0.1	6	------	nw.	----	------	----	14	11	5	----	0.0	0.0
Sandy Hook	22	10	55	29.97	29.99	------	71.9	------	94	11	78	53	29	65	21	65	62	77	0.97	−2.5	7	9,048	sw.	37	nw.	24	15	8	7	4.4	0.0	0.0
Trenton	190	159	183	29.81	30.01	------	71.4	+4.5	95	11	81	46	29	62	28	64	61	74	1.06	−2.3	4	5,823	sw.	28	nw.	24	16	7	7	4.0	0.0	0.0
Baltimore	123	100	215	29.89	30.02	−.06	76.0	+7.5	99	22	85	50	29	67	25	66	62	66	2.05	−1.3	7	6,093	sw.	42	sw.	23	17	7	6	3.5	0.0	0.0
Washington	112	62	85	29.91	30.03	−.05	74.1	+6.0	97	22	84	49	29	64	28	66	63	75	2.79	−0.4	9	3,199	sw.	33	nw.	23	18	6	6	3.6	0.0	0.0
Cape Henry	18	8	54	30.02	30.04	------	76.4	+4.6	95	22	84	53	30	69	22	69	66	76	2.70	−0.2	4	7,273	sw.	44	nw.	23	18	10	2	3.1	0.0	0.0
Lynchburg	681	153	188	29.32	30.06	−.02	73.8	+4.8	96	22	85	46	30	63	31	65	62	73	0.73	−2.6	5	3,225	w.	34	n.	23	17	8	5	3.7	0.0	0.0
Norfolk	91	170	205	29.96	30.06	.00	76.4	+4.8	96	23	85	57	30	68	28	68	64	74	1.45	−1.8	6	7,262	sw.	42	nw.	23	17	9	4	3.5	0.0	0.0
Richmond	144	11	52	29.91	30.06	−.01	74.4	+3.9	97	22	85	46	30	64	30	68	66	82	1.92	−1.3	4	4,111	sw.	31	n.	23	17	7	6	3.4	0.0	0.0
Wytheville	2,304	49	55	27.76	30.08	+.01	67.6	+4.0	89	21	80	38	30	56	31	61	59	80	2.06	−1.2	8	2,721	w.	18	w.	26	17	11	2	3.8	0.0	0.0
South Atlantic States							77.4	+4.1										75	1.22	−3.0										3.6		
Asheville	2,253	89	104	27.80	30.09	+.02	71.0	+6.0	91	21	83	38	29	59	35	63	60	78	1.12	−1.9	3	3,637	nw.	20	nw.	27	15	13	2	3.7	0.0	0.0
Charlotte	779	55	62	29.25	30.07	.00	77.0	+5.5	98	18	88	46	30	67	27	67	63	68	1.15	−1.8	3	2,438	s.	14	w.	2	18	11	1	3.1	0.0	0.0
Greensboro	886	6	56	29.14	30.08	------	73.4	------	97	23	85	42	30	62	33	66	64	82	0.51	------	3	4,246	sw.	24	sw.	26	15	8	7	4.1	0.0	0.0
Hatteras	11	5	50	30.04	30.05	−.01	77.2	+2.5	90	18	83	63	28	71	21	72	70	80	1.70	−2.9	6	7,287	sw.	35	nw.	28	17	8	5	3.4	0.0	0.0
Raleigh	376	103	146	29.68	30.06	−.01	76.2	+5.1	97	23	86	48	30	66	26	67	63	70	2.37	−1.2	3	4,535	sw.	23	n.	23	17	10	3	3.6	0.0	0.0
Wilmington	78	81	91	30.01	30.09	+.04	76.8	+3.7	98	18	86	52	30	68	24	70	67	79	0.12	−4.4	1	3,732	sw.	18	sw.	26	22	6	2	2.9	0.0	0.0
Charleston	48	11	92	30.02	30.06	+.02	78.7	+2.1	98	18	85	56	28	72	23	73	70	80	2.08	−2.4	5	6,311	e.	26	e.	19	15	10	5	4.0	0.0	0.0
Columbia, S. C	351	41	57	29.70	30.07	+.02	78.6	+4.1	99	18	89	52	29	68	27	68	63	68	0.56	−2.9	3	3,917	s.	20	sw.	26	20	7	3	3.1	0.0	0.0
Duo West	711	10	55	29.34	30.10	------	77.5	------	99	18	89	48	28	66	28	----	----	----	0.84	------	6	4,445	sw.	25	nw.	2	15	11	4	3.7	0.0	0.0
Greenville, S. C	1,039	139	146	29.00	30.07	------	77.1	+6.5	97	18	86	51	30	68	24	66	62	66	2.62	−1.1	7	4,291	n.	26	w.	2	19	8	3	3.1	0.0	0.0
Augusta	182	62	77	29.86	30.05	.00	80.2	+4.9	104	18	92	52	28	69	33	70	66	71	0.40	−3.0	3	2,774	se.	18	nw.	3	19	10	1	3.2	0.0	0.0
Savannah	65	150	194	29.98	30.05	+.02	79.2	+3.0	100	18	88	56	29	71	27	72	70	81	1.25	−4.2	6	6,291	e.	28	w.	26	16	9	5	4.1	0.0	0.0
Jacksonville	43	209	245	29.99	30.04	+.04	80.0	+1.7	95	19	87	60	28	73	21	73	70	80	0.07	−7.3	2	6,675	ne.	27	ne.	30	12	15	3	4.4	0.0	0.0
Florida Peninsula							81.1	+0.4										82	12.47	+5.3										6.3		
Key West	22	10	64	29.93	29.95	+0.1	82.0	−0.2	90	9	87	70	6	77	15	77	75	81	9.10	+2.4	15	5,848	e.	29	w.	28	7	12	11	6.0	0.0	0.0
Miami	25	124	168	29.96	29.99	+.01	81.2	+1.1	90	11	86	70	6	76	16	75	73	80	19.70	+11.4	20	6,423	e.	30	s.	7	1	14	15	7.3	0.0	0.0
Tampa	35	79	197	29.97	30.00	+.03	80.3	+0.4	93	2	88	62	28	72	21	74	72	84	8.61	+2.2	21	6,848	e.	35	ne.	10	4	14	12	6.2	0.0	0.0
Titusville	44	5	----	29.97	30.02	------	81.4	------	95	3	89	62	29	74	21	----	----	----	3.01	------	12	------	ne.	----	------	----	4	20	6	5.6	0.0	0.0
East Gulf States							79.8	+4.1										72	1.30	−2.9										3.4		
Atlanta	1,173	190	198	28.86	30.07	+.02	77.5	+5.1	97	18	87	50	28	68	26	66	61	64	1.32	−1.7	3	4,886	e.	24	w.	26	17	11	2	3.4	0.0	0.0
Macon	370	78	87	29.67	30.06	+.03	78.4	+3.6	99	18	89	51	28	68	31	69	66	72	2.50	−0.7	5	2,968	e.	18	nw.	27	18	8	4	3.3	0.0	0.0
Thomasville	273	49	103	29.75	30.04	+.03	79.4	+2.6	100	19	90	53	28	69	28	71	68	76	2.08	−2.8	7	3,939	ne.	24	s.	2	17	8	5	3.9	0.0	0.0
Apalachicola	36	11	51	29.99	30.03	------	79.9	------	92	19	86	58	28	74	20	74	71	77	2.41	−5.7	10	5,102	se.	29	e.	14	21	3	6	3.0	0.0	0.0
Pensacola	56	149	185	29.97	30.03	+.04	79.4	+1.4	92	7	85	57	28	74	17	73	70	78	1.43	−3.9	4	7,086	s.	30	nw.	3	14	14	2	3.7	0.0	0.0
Anniston	741	9	57	------	------	------	78.6	+7.3	101	19	91	48	28	66	31	----	----	----	0.79	−2.9	2	2,349	s.	13	nw.	27	14	14	2	----	0.0	0.0
Birmingham	700	11	48	29.30	30.06	+.03	81.0	+6.2	102	19	93	50	28	69	30	68	63	66	0.14	−3.2	4	3,241	se.	19	se.	23	16	13	1	3.3	0.0	0.0
Mobile	57	125	161	29.97	30.03	+.03	80.4	+2.3	96	8	89	54	29	72	27	72	70	80	1.92	−3.1	8	5,083	n.	25	n.	3	14	12	4	3.8	0.0	0.0
Montgomery	223	100	112	29.80	30.05	+.03	81.0	+4.7	100	7	92	54	29	70	27	69	64	64	0.63	−2.4	5	3,384	e.	24	e.	14	19	8	3	3.3	0.0	0.0
Corinth	469	6	----	------	------	------	80.0	------	100	17	94	45	29	67	38	----	----	----	0.14	------	1	------	se.	----	------	----	14	16	0	----	0.0	0.0
Meridian	375	87	95	29.65	30.03	+.01	79.2	+4.7	97	24	90	47	29	68	32	70	66	70	0.23	−2.7	4	2,586	se.	14	sw.	2	18	10	2	3.3	0.0	0.0
Vicksburg	247	65	73	29.77	30.05	+.03	80.3	+4.0	96	9	91	52	29	70	29	70	66	69	0.08	−2.8	3	3,469	se.	17	se.	5	18	12	0	3.0	0.0	0.0
New Orleans	53	76	84	29.96	30.01	+.03	82.3	+3.1	96	8	90	62	28	75	22	74	72	78	2.06	−3.0	8	3,706	se.	20	e.	5	12	14	4	4.0	0.0	0.0
West Gulf States							81.5	+4.5										70	1.15	−2.5										3.1		
Shreveport	249	204	220	29.74	30.00	.00	82.1	+5.2	99	5	93	58	27	71	29	70	65	65	0.74	−2.1	5	5,337	s.	36	sw.	3	22	7	1	2.7	0.0	0.0
Bentonville	1,303	11	44	28.66	29.99	−.03	76.1	+7.2	95	18	88	43	27	64	33	----	----	----	0.53	------	5	2,353	s.	17	s.	21	26	4	0	----	0.0	0.0
Fort Smith	457	79	94	29.51	29.98	−.03	79.5	+5.5	97	17	90	50	27	69	31	69	66	69	0.77	−2.2	4	4,027	e.	30	se.	12	24	5	1	2.5	0.0	0.0
Little Rock	357	136	153	29.64	30.01	−.02	79.9	+5.8	96	25	90	54	30	70	29	70	65	68	0.64	−2.5	6	4,597	s.	24	s.	4	19	9	2	2.8	0.0	0.0
Austin	605	136	148	29.34	29.97	------	83.0	+4.7	98	5	94	58	30	72	29	70	66	65	0.02	−3.4	1	4,277	se.	28	se.	12	13	17	0	3.7	0.0	0.0
Brownsville	57	83	100	29.88	29.95	------	82.0	+1.4	92	3	89	70	29	75	19	75	73	83	1.43	−4.1	11	5,159	e.	26	se.	1	10	18	2	4.3	0.0	0.0
Corpus Christi	20	11	78	29.95	29.97	+.02	83.1	+3.4	90	20	88	74	30	78	14	76	74	80	0.83	−3.7	9	6,507	se.	24	se.	12	17	9	4	3.9	0.0	0.0
Dallas	512	220	227	29.44	29.98	------	82.0	------	100	5	92	58	30	72	25	----	----	----	2.76	0.0	2	6,930	se.	27	so.	20	24	5	1	1.7	0.0	0.0
Fort Worth	670	106	114	29.25	29.96	−.03	83.0	+6.1	101	4	94	59	30	72	26	69	62	56	1.25	−1.2	2	5,635	s.	27	se.	20	23	5	2	3.0	0.0	0.0
Galveston	54	106	114	29.96	30.02	+.04	82.4	+2.3	94	9	86	70	29	78	16	75	72	76	0.94	−4.6	8	6,162	se.	21	e.	27	20	7	3	3.2	0.0	0.0
Houston	138	292	314	29.85	30.00	------	81.6	+2.6	97	3	90	59	29	73	26	----	----	----	2.27	−1.8	5	6,528	se.	35	e.	10	18	10	2	3.2	0.0	0.0
Palestine	510	64	72	29.48	30.00	+.01	81.3	+4.3	97	25	92	55	30	70	29	70	65	67	0.01	−2.9	1	4,038	s.	20	s.	12	19	10	1	2.8	0.0	0.0
Port Arthur	34	58	66	29.96	30.00	------	82.0	------	97	9	90	64	29	74	23	74	71	76	2.03	−2.8	10	4,470	s.	41	e.	5	16	12	2	3.2	0.0	0.0
San Antonio	693	242	301	29.24	29.94	−.02	83.2	+4.2	98	4	94	65	30	73	26	72	67	68	0.01	−3.0	1	7,075	e.	42	e.	12	15	15	0	3.3	0.0	0.0
Taylor	571	38	51	29.42	30.02	+.05	82.6	+5.7	100	5	94	58	30	71	32	----	----	----	2.40	−0.9	3	4,727	s.	29	s.	12	18	11	1	3.3	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							73.9	+5.2										72	3.34	+0.4										4.0		
Chattanooga	762	190	215	29.25	30.04	−0.02	278.2	+6.0	97	18	89	50	30	67	30	67	61	62	0.51	−2.6	5	3,932	se.	24	sw.	2	16	12	2	3.5	0.0	0.0
Knoxville	995	102	111	29.03	30.07	+.01	76.8	+6.2	98	18	88	47	29	65	30	66	62	69	1.95	−0.7	4	3,163	sw.	30	se.	19	20	8	2	3.2	0.0	0.0
Memphis	399	76	97	29.61	30.03	.00	79.8	+6.2	96	10	89	52	27	71	27	69	65	66	0.57	−2.2	2	4,387	s.	25	sw.	25	21	7	2	3.0	0.0	0.0
Nashville	546	168	191	29.49	30.06	.00	77.2	+5.4	98	18	88	46	29	66	34	67	63	69	1.54	−1.9	6	4,514	ne.	28	nw.	25	13	13	4	3.6	0.0	0.0
Lexington	989	193	230	29.03	30.08	+.01	73.4	+4.9	93	21	82	47	29	64	32	-----	-----	-----	2.15	−0.9	8	7,356	s.	31	nw.	25	20	6	4	2.9	0.0	0.0
Louisville	525	188	234	29.48	30.09	.00	75.2	+4.7	94	21	84	49	28	66	31	66	62	70	3.56	+0.8	6	5,476	s.	33	n.	27	14	11	5	3.9	0.0	0.0
Evansville	431	76	116	29.58	30.04	−.02	76.2	+5.5	96	17	86	50	30	66	30	67	63	71	4.45	+1.1	5	4,776	s.	28	sw.	25	16	9	5	3.8	0.0	0.0
Indianapolis	822	194	230	29.16	30.03	−.03	72.8	+5.9	92	11	82	47	28	64	28	64	60	72	3.66	+0.3	9	6,073	sw.	30	nw.	3	17	7	6	3.9	0.0	0.0
Royal Center	736	11	55	29.24	30.03	-----	69.2	-----	93	11	80	38	28	59	32	-----	-----	-----	4.16	+1.3	10	4,892	s.	24	nw.	26	13	10	7	4.7	0.0	0.0
Terre Haute	575	96	129	29.42	30.02	-----	73.2	-----	93	17	83	46	28	64	27	65	62	76	9.64	+6.0	8	5,130	s.	26	sw.	1	14	10	6	4.1	0.0	0.0
Cincinnati	627	11	51	29.38	30.06	−.01	72.7	+5.6	94	10	83	42	29	62	32	64	61	76	4.71	+2.1	8	3,556	sw.	17	sw.	25	16	8	6	3.8	0.0	0.0
Columbus	822	216	230	29.18	30.04	−.03	71.4	+4.9	92	10	81	45	28	62	27	63	60	73	3.34	+0.8	12	5,700	s.	34	sw.	23	14	9	7	4.2	0.0	0.0
Dayton	899	137	173	29.10	30.04	-----	72.0	+5.4	93	11	82	44	28	62	29	64	60	74	2.36	−0.6	8	4,593	sw.	28	sw.	23	12	13	5	4.1	0.0	0.0
Elkins	1,947	59	67	28.09	30.11	+.03	66.3	+3.3	90	12	78	39	30	55	35	60	59	89	3.82	+0.7	14	2,435	w.	28	sw.	2	7	14	9	6.0	0.0	0.0
Parkersburg	637	77	82	29.43	30.08	.00	72.4	+5.1	95	12	82	41	30	62	33	64	60	74	3.27	+0.5	11	2,925	se.	32	nw.	25	12	10	8	5.0	0.0	0.0
Pittsburgh	842	353	410	29.16	30.04	−.04	70.3	+3.9	93	12	79	42	29	61	27	63	59	73	3.81	+1.2	11	5,768	sw.	31	sw.	23	11	9	10	4.9	0.0	0.0
Lower Lake Region							68.4	+5.5										73	3.25	+0.3										5.1		
Buffalo	767	247	280	29.18	29.99	−.07	66.4	+4.0	83	13	73	45	25	60	22	61	58	78	4.10	+1.2	9	9,087	sw.	56	w.	1	11	9	10	5.2	0.0	0.0
Canton	448	10	61	29.49	29.96	-----	62.9	+3.6	90	13	73	37	25	53	32	-----	-----	-----	5.69	+2.3	15	4,821	sw.	26	w.	22	10	13	7	5.3	0.0	0.0
Ithaca	836	74	100	29.11	30.00	-----	67.8	+6.2	100	12	80	39	25	56	40	60	56	71	2.99	−0.1	10	5,287	nw.	26	sw.	2	10	12	8	5.1	0.0	0.0
Oswego	335	71	85	29.62	29.98	−.08	66.8	+5.6	93	13	75	47	30	59	32	60	57	73	2.73	0.0	15	5,174	s.	22	nw.	24	9	9	12	5.6	0.0	0.0
Rochester	523	86	162	29.45	30.01	−.05	68.1	+5.7	95	12	78	42	25	58	32	60	56	71	2.85	+0.4	12	4,881	sw.	29	w.	22	8	13	9	5.3	0.0	0.0
Syracuse	596	65	79	29.37	30.01	−.06	68.6	+7.0	97	11	78	42	25	59	35	-----	-----	-----	2.76	0.0	12	3,909	s.	20	w.	24	8	11	11	6.3	0.0	0.0
Erie	714	130	166	29.25	30.01	−.05	69.2	+5.6	92	13	77	46	29	61	27	62	59	74	2.27	−1.1	11	8,016	s.	41	sw.	1	12	10	8	4.6	0.0	0.0
Cleveland	762	267	337	29.21	30.02	−.01	69.8	+5.9	90	21	76	51	29	63	20	62	58	70	3.93	+0.6	12	8,363	s.	40	se.	25	10	12	8	5.2	0.0	0.0
Sandusky	629	5	67	29.35	30.03	−.03	70.6	+5.3	95	11	79	45	29	62	26	-----	-----	-----	3.63	+0.7	9	4,787	sw.	28	sw.	1	11	8	11	5.3	0.0	0.0
Toledo	628	208	243	29.35	30.03	−.03	70.2	+5.8	95	11	78	44	28	62	25	62	58	71	3.23	+0.4	11	7,861	sw.	31	s.	14	15	7	8	4.4	0.0	0.0
Fort Wayne	856	100	119	29.11	30.02	-----	70.5	+5.0	95	11	80	46	28	61	30	62	59	73	2.08	−1.0	8	5,316	sw.	26	w.	26	16	7	7	4.3	0.0	0.0
Detroit	730	218	258	29.24	30.02	−.04	69.8	+6.3	95	11	78	48	28	62	25	62	59	73	2.97	+0.1	11	6,017	sw.	29	sw.	1	11	11	8	5.1	0.0	0.0
Upper Lake Region							65.6	+6.1										78	4.69	+1.4										5.1		
Alpena	609	13	92	29.33	29.99	−.04	63.8	+6.2	98	11	74	41	28	54	32	58	56	81	4.34	+1.4	16	6,840	nw.	38	se.	25	10	12	8	4.8	0.0	0.0
Escanaba	612	54	60	29.30	29.95	−.06	63.4	+6.3	87	9	71	42	27	56	27	58	56	81	6.88	+3.6	12	6,002	s.	34	ne.	26	13	10	7	4.6	0.0	0.0
Grand Haven	632	54	89	29.31	29.98	−.06	65.6	+4.7	85	11	73	41	28	58	26	61	59	80	3.42	−0.2	12	7,094	s.	37	sw.	1	14	7	9	4.9	0.0	0.0
Grand Rapids	707	70	244	29.24	30.00	−.05	69.0	+6.3	94	10	79	44	28	59	30	61	57	74	4.09	+0.6	10	7,227	sw.	44	sw.	22	9	12	9	5.2	0.0	0.0
Houghton	668	64	99	29.20	29.92	−.08	63.3	+6.4	98	11	71	46	28	55	32	-----	-----	-----	3.66	+0.1	14	5,763	w.	35	nw.	13	8	12	10	5.9	0.0	0.0
Lansing	878	6	88	29.07	30.00	-----	66.5	+5.1	93	11	77	38	28	56	32	61	59	83	3.33	+0.4	14	4,920	sw.	23	sw.	5	9	12	9	5.4	0.0	0.0
Ludington	637	60	66	29.29	29.98	-----	65.2	+5.9	83	10	72	46	28	59	26	60	58	80	6.87	+3.6	12	6,664	s.	34	sw.	1	13	13	4	3.9	0.0	0.0
Marquette	734	77	111	29.14	29.94	−.06	64.5	+7.0	98	11	72	46	24	57	27	57	54	76	5.66	+2.4	15	6,211	w.	30	sw.	29	10	8	12	6.0	0.0	0.0
Port Huron	638	70	120	29.30	29.99	−.07	67.4	+5.8	98	11	76	45	28	59	28	61	58	77	2.92	+0.1	12	6,507	s.	26	nw.	14	9	11	10	5.3	0.0	0.0
Sault Ste. Marie	614	11	52	29.29	29.98	−.04	60.9	+5.4	92	10	69	41	25	53	31	56	54	83	6.72	+2.5	16	4,320	se.	22	nw.	17	10	14	6	5.1	0.0	0.0
Chicago	673	7	131	29.29	30.01	−.03	71.2	+6.0	94	10	79	50	29	63	27	63	60	76	5.14	+2.0	13	6,107	sw.	26	sw.	5	12	10	8	4.9	0.0	0.0
Green Bay	617	109	141	29.29	29.95	−.07	67.2	+6.8	97	10	76	45	27	58	29	60	56	74	5.84	+2.3	14	6,494	s.	30	ne.	14	9	11	10	5.8	0.0	0.0
Milwaukee	681	125	221	29.25	29.98	−.05	69.6	+7.1	97	10	78	48	27	61	31	62	58	74	3.15	−0.1	10	8,224	sw.	39	w.	13	13	10	7	4.7	0.0	0.0
Duluth	1,133	5	47	28.70	29.91	−.07	61.4	+6.3	92	8	70	37	24	52	30	54	51	79	3.63	+0.3	13	6,802	ne.	34	nw.	23	12	10	8	5.0	0.0	0.0
North Dakota							62.3	+5.1										66	1.86	+0.2										3.5		
Moorhead	940	50	58	28.86	29.86	−.10	64.9	+6.7	101	7	77	31	24	52	40	55	49	66	1.64	−0.6	11	5,210	s.	30	sw.	11	14	11	5	4.0	0.0	0.0
Bismarck	1,674	8	57	28.09	29.85	−.09	63.2	+5.1	105	7	77	37	26	50	46	53	46	64	2.81	+1.6	8	5,692	e.	31	nw.	29	21	5	4	2.6	0.0	0.0
Devils Lake	1,478	11	44	28.30	29.86	−.08	60.4	+4.5	99	7	73	36	24	48	38	52	47	73	2.72	+1.1	7	5,575	se.	28	ne.	8	15	9	6	4.3	0.0	0.0
Ellendale	1,457	10	56	28.32	29.86	-----	64.2	-----	103	10	80	33	24	49	49	-----	-----	-----	0.89	−1.1	6	8,120	nw.	34	sw.	29	17	9	4	3.4	0.0	0.0
Grand Forks	833	12	67	-----	-----	-----	62.0	-----	100	7	76	35	24	48	40	53	-----	-----	2.44	-----	9	-----	se.	31	sw.	11	14	12	4	-----	0.0	0.0
Williston	1,878	41	48	27.90	29.85	−.08	60.8	+4.2	99	6	74	36	23	48	42	50	43	60	1.23	+0.1	8	5,101	w.	31	se.	18	19	7	4	3.0	0.0	0.0
Upper Mississippi Valley							72.0	+6.9										73	4.48	+0.9										4.4		
Minneapolis	918	102	208	28.92	29.89	-----	68.6	+7.2	104	10	78	43	24	59	31	-----	-----	-----	2.42	−0.7	12	6,877	s.	26	se.	24	12	10	8	4.7	0.0	0.0
St. Paul	837	114	149	29.01	29.90	−.09	68.2	+6.9	101	10	78	42	24	58	32	-----	-----	-----	2.56	−0.5	13	4,969	sw.	35	sw.	20	13	8	9	4.6	0.0	0.0
La Crosse	714	11	48	29.18	29.94	−.07	68.5	+6.3	99	10	79	41	27	58	33	61	58	77	3.75	−0.2	14	2,781	s.	16	s.	21	13	8	9	4.9	0.0	0.0
Madison	974	70	78	28.94	29.96	−.07	68.4	+6.0	95	10	77	46	27	60	29	61	57	74	7.17	+3.4	12	4,967	s.	26	sw.	20	12	9	9	4.7	0.0	0.0
Wausau	1,247	4	62	28.64	29.96	-----	65.4	-----	99	10	76	37	27	55	33	-----	-----	-----	3.70	0.0	14	3,635	s.	18	w.	5	17	5	8	4.4	0.0	0.0
Charles City	1,015	10	51	28.89	29.95	−.05	69.0	+8.0	98	10	80	40	24	58	35	60	57	73	7.40	+3.7	11	4,360	se.	19	s.	11	12	12	6	4.4	0.0	0.0
Davenport	606	71	79	29.33	29.98	−.05	72.4	+6.8	95	9	82	46	27	63	29	64	60	71	3.78	+0.2	10	5,707	s.	27	s.	13	12	7	11	5.1	0.0	0.0
Des Moines	861	5	99	29.04	29.93	−.09	72.4	+6.8	98	7	83	43	27	02	33	63	59	70	4.44	+0.8	11	6,102	s.	30	sw.	16	12	9	9	4.9	0.0	0.0
Dubuque	700	81	96	29.22	29.96	−.07	70.0	+6.0	96	16	79	44	27	61	32	62	58	73	6.67	+2.7	13	3,442	s.	16	nw.	25	12	8	10	4.9	0.0	0.0
Keokuk	614	64	78	29.33	29.99	−.04	74.0	+6.5	95	7	84	46	27	64	28	65	62	72	6.73	+2.9	12	4,139	s.	30	sw.	14	15	9	6	4.3	0.0	0.0
Cairo	358	87	93	29.65	30.02	−.03	77.0	+5.5	95	18	86	50	30	68	31	68	65	76	1.19	−1.7	5	4,295	s.	30	sw.	25	14	10	6	4.2	0.0	0.0
Peoria	609	11	45	29.35	30.02	−.02	73.0	+8.7	96	11	84	41	28	62	31	64	62	77	4.92	+0.9	11	3,155	s.	19	w.	14	18	7	5	3.3	0.0	0.0
Springfield, Ill	636	5	191	29.33	30.00	−.05	74.8	+7.2	97	16	86	48	28	64	32	65	01	71	3.15	−0.5	9	7,368	s.	30	s.	1	11	13	6	4.7	0.0	0.0
Hannibal	534	74	109	29.42	29.99	−.04	75.2	+7.5	95	15	85	46	28	65	31	-----	-----	-----	3.72	−0.2	10	5,151	sw.	27	s.	22	14	10	6	4.1	0.0	0.0
St. Louis	568	265	303	29.40	30.00	−.04	76.9	+6.8	96	15	86	51	27	68	27	67	62	68	5.66	+2.2	8	7,470	sw.	30	sw.	21	20	7	3	3.2	0.0	0.0
Missouri Valley							73.6	+7.5										61	5.37	+0.2										3.7		
Columbia, Mo	784	6	84	29.16	29.98	−.05	75.2	+7.0	96	15	85	44	27	65	28	-----	-----	-----	6.69	+2.3	7	4,317	s.	32	nw.	21	15	12	3	3.5	0.0	0.0
Kansas City	963	161	181	28.95	29.95	−.07	77.5	+8.6	102	5	88	49	27	67	30	65	60	63	5.12	+0.6	10	5,243	se.	31	sw.	25	16	9	5	3.3	0.0	0.0
St. Joseph	967	11	49	28.92	29.93	-----	76.2	-----	101	5	87	45	27	66	31	65	61	68	7.88	+4.0	9	5,188	sc.	34	nw.	24	19	6	5	3.2	0.0	0.0
Springfield, Mo	1,324	98	104	28.62	30.00	−.03	75.2	+6.3	94	6	85	47	27	66	25	66	62	70	0.92	−2.6	7	6,088	s.	26	s.	21	22	7	1	1.8	0.0	0.0
Iola	984	11	50	28.93	29.95	−.06	79.0	+9.2	101	5	91	46	27	66	34	-----	-----	-----	1.50	−3.4	5	3,944	s.	18	nw.	25	18	7	5	3.4	0.0	0.0
Topeka	987	92	107	-----	-----	-----	77.2	+8.5	102	5	88	48	26	66	32	-----	-----	-----	4.59	+0.8	8	6,580	sw.	28	sw.	20	16	7	7	3.3	0.0	0.0
Lincoln	1,189	11	81	28.65	29.89	−.10	74.6	+8.2	102	6	86	44	26	64	35	63	57	63	3.79	+0.8	10	6,929	s.	33	nw.	24	15	11	4	4.1	0.0	0.0
Omaha	1,105	115	122	28.75	29.91	−.09	73.7	+6.9	102	6	84	46	27	64	33	62	57	64	3.74	+0.5	10	4,561	s.	21	n.	17	17	8	5	3.6	0.0	0.0
Valentine	2,598	47	54	27.22	29.89	−.07	68.2	+5.7	106	9	82	36	26	54	45	55	47	57	0.93	−0.4	7	5,281	w.	31	nw.	25	9	13	8	4.8	0.0	0.0
Sioux City	1,135	94	164	28.69	29.88	−.10	71.8	+8.4	101	7	82	42	27	62	36	60	53	59	3.34	+0.3	7	8,172	s.	35	s.	11	12	7	11	4.8	0.0	0.0
Huron	1,306	59	74	28.50	29.88	−.08	68.6	+7.3	103	9	82	37	23	55	48	56	48	57	1.52	0.0	10	6,424	s.	33	sw.	11	14	13	3	3.7	0.0	0.0
Pierre	1,572	70	75	28.20	29.84	−.11	70.2	+6.4	108	9	84	38	23	57	45	55	45	51	1.43	+0.3	5	5,718	e.	31	nw.	29	16	8	6	4.0	0.0	0.0
Yankton	1,233	49	57	28.54	29.87	−.11	71.9	+7.9	103	7	83	44	26	61	43	-----	-----	-----	2.32	−0.4	8	4,597	s.	24	s.	11	12	8	10	4.6	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0-10	In.	In
Northern Slope							60.8	+3.4										53	1.17	0.0										4.5		
Billings	3,140	5	---	---	---	---	59.6	---	100	4	76	33	25	49	48	---	---	---	1.68	---	6	---	nw.	---	---	---	9	14	7	---	0.0	0.0
Havre	2,505	11	44	27.28	29.89	−0.05	58.7	+2.3	98	5	72	28	23	45	46	47	38	55	0.47	−0.8	7	5,452	sw.	31	sw.	11	10	15	5	4.9	0.0	0.0
Helena	4,110	87	112	25.77	29.92	−.05	56.6	0.0	90	4	68	32	23	46	37	46	38	56	1.18	−0.1	11	5,426	sw.	29	se.	5	6	10	14	6.1	T.	0.0
Kalispell	2,973	48	56	26.90	29.93	−.03	54.8	+1.3	90	3	66	29	23	44	38	47	40	64	2.89	+1.6	9	3,408	nw.	29	sw.	6	4	9	17	6.6	0.0	0.0
Miles City	2,371	48	55	27.38	29.89	−.06	64.4	+3.2	98	6	77	32	23	52	41	51	41	50	0.67	−0.4	3	3,851	s.	25	w.	11	18	9	3	3.5	0.0	0.0
Rapid City	3,259	50	58	26.54	29.88	−.08	67.6	+7.2	101	7	81	39	26	54	39	51	39	42	0.22	−1.0	4	4,673	w.	30	sw.	18	14	11	5	3.8	0.0	0.0
Cheyenne	6,088	84	101	24.04	29.89	−.07	61.8	+4.8	87	10	75	35	22	48	37	47	37	47	0.75	−0.4	5	7,053	w.	39	w.	25	17	7	6	3.8	0.0	0.0
Lander	5,372	60	68	24.63	29.89	−.07	59.8	+4.1	90	4	75	32	22	45	40	47	36	50	1.73	+0.8	5	3,620	sw.	35	sw.	10	20	7	3	2.5	2.1	0.0
Sheridan	3,790	10	47	26.04	29.89	---	60.3	---	97	4	76	34	27	44	47	48	40	58	2.08	+0.8	9	2,666	nw.	24	s.	5	14	10	6	4.3	0.0	0.0
Yellowstone Park	6,241	11	48	23.90	29.94	−.03	52.6	−0.8	83	4	66	25	23	39	39	41	32	55	1.30	0.0	8	4,928	sw.	31	sw.	12	12	8	10	5.1	0.8	0.0
North Platte	2,821	11	51	27.00	29.87	−.10	71.0	+8.9	105	5	85	36	26	57	47	56	47	53	0.41	−0.9	6	4,430	s.	23	s.	8	14	11	5	4.3	0.0	0.0
Middle Slope							76.0	+7.9										49	1.43	−0.6										3.3		
Denver	5,292	106	113	24.73	29.88	−.08	68.2	+5.3	94	9	81	39	23	55	34	51	38	40	0.22	−0.8	4	4,276	s.	24	s.	6	15	12	3	3.8	0.0	0.0
Pueblo	4,685	80	86	25.28	29.86	−.10	71.0	+6.4	96	9	85	43	27	57	40	53	41	41	0.72	0.0	3	4,434	nw.	28	nw.	12	13	14	3	4.1	0.0	0.0
Concordia	1,392	50	58	28.47	29.91	−.08	77.6	+9.3	107	5	89	45	26	67	34	63	56	56	1.96	−0.6	7	5,952	s.	31	nw.	24	18	8	4	3.5	0.0	0.0
Dodge City	2,509	88	100	27.38	29.91	−.07	77.8	+8.4	103	5	90	46	26	65	35	61	51	48	0.69	−1.2	5	10,266	s.	34	sw.	19	23	5	2	2.0	0.0	0.0
Wichita	1,358	139	158	28.52	29.91	−.09	79.4	+8.8	103	5	91	50	26	68	31	64	56	53	4.58	+1.5	4	9,269	s.	37	sw.	14	18	6	6	3.6	0.0	0.0
Oklahoma City	1,214	10	47	28.69	29.93	−.06	82.2	+9.4	103	5	94	54	26	17	29	67	60	56	0.43	−2.6	2	6,343	s.	24	nw.	1	21	9	0	3.0	0.0	0.0
Southern Slope							79.9	+6.4										52	0.14	−2.4												
Abilene	1,738	10	52	28.17	29.92	−.04	83.4	+8.1	100	5	95	63	30	72	27	66	57	49	0.09	−2.6	1	6,955	s.	29	s.	20	24	4	2	2.5	0.0	0.0
Amarillo	3,676	10	49	26.28	29.92	−.04	76.8	+7.5	97	5	90	54	22	64	32	60	52	50	0.51	−1.8	3	6,458	s.	20	se.	20	21	7	2	2.5	0.0	0.0
Del Rio	944	64	71	28.92	29.88	−.06	83.2	+4.0	98	25	93	66	30	73	26	70	64	60	T.	−3.0	0	6,388	se.	24	se.	12	17	13	0	3.3	0.0	0.0
Roswell	3,566	75	85	26.36	29.89	−.03	76.2	+5.9	95	4	90	50	22	63	41	61	53	51	0.02	−2.1	1	4,395	s.	26	s.	22	15	14	1	3.5	0.0	0.0
Southern Plateau							72.9	+2.2										54	1.36	+0.6										3.6		
El Paso	3,778	152	175	26.16	29.84	−.04	79.2	+5.3	96	9	90	60	21	68	30	63	55	50	1.10	−0.2	7	4,506	e.	31	sw.	13	14	15	1	3.8	0.0	0.0
Albuquerque	4,972	51	66	25.08	29.86	---	70.0	---	92	4	83	44	22	57	38	57	50	60	2.18	---	9	2,860	sw.	27	nw.	23	10	13	7	5.1	0.0	0.0
Santa Fe	7,013	38	53	23.34	29.89	−.04	63.4	+2.5	85	4	74	38	21	52	31	52	46	64	4.59	+3.1	16	3,261	e.	21	ne.	5	7	17	6	5.3	0.0	0.0
Flagstaff	6,907	10	59	23.41	29.85	−.04	58.4	+2.9	80	6	72	28	21	45	41	49	---	65	2.08	---	7	4,960	sw.	35	sw.	19	14	9	7	---	0.0	0.0
Phoenix	1,108	10	107	28.64	29.76	−.05	85.9	+3.2	107	7	99	58	21	73	38	66	55	41	0.23	−0.5	3	2,952	e.	24	sw.	19	21	6	3	2.3	0.0	0.0
Yuma	141	9	54	29.62	29.76	−.02	83.6	−0.1	108	6	99	58	11	69	41	67	57	49	0.74	+0.4	4	2,596	w.	21	n.	20	26	3	1	1.5	0.0	0.0
Independence	3,957	6	27	25.91	29.89	+.03	67.4	−0.6	92	2	83	42	21	52	40	49	---	---	0.12	0.0	1	---	s.	---	---	---	26	3	1	---	0.0	0.0
Middle Plateau							62.9	+1.0										41	0.76	+0.1										2.5		
Reno	4,532	74	81	25.44	29.89	−.06	60.2	+0.5	95	3	76	32	23	45	42	46	32	42	0.63	+0.4	3	3,945	sw.	40	w.	28	20	8	2	2.4	T.	0.0
Tonopah	6,090	12	20	---	---	---	61.0	---	83	2	72	35	23	50	32	46	32	39	0.96	---	2	---	se.	---	---	---					0.0	0.0
Winnemucca	4,344	18	56	25.59	29.94	+.01	58.8	−0.4	97	3	76	28	24	41	50	44	30	41	0.33	−0.1	6	4,038	sw.	26	w.	18	19	8	3	2.9	0.0	0.0
Modena	5,473	10	43	24.60	29.86	−.06	60.8	+0.8	85	2	78	30	25	44	45	45	29	38	0.39	−0.4	1	7,779	sw.	41	sw.	8	24	4	2	1.8	0.0	0.0
Salt Lake City	4,360	163	203	25.58	29.88	−.07	65.6	+1.2	91	7	77	42	24	54	30	50	36	38	0.56	−0.4	6	5,429	se.	34	nw.	15	21	6	3	2.8	0.0	0.0
Grand Junction	4,602	60	68	25.35	29.88	−.07	69.0	+2.8	93	6	82	44	25	56	36	53	42	47	1.87	+1.0	9	4,274	se.	33	s.	6	20	8	2	2.7	0.0	0.0
Northern Plateau							61.8	+1.1										48	0.76	0.0										4.4		
Baker	3,471	48	53	26.43	29.98	−.01	55.8	−0.2	94	3	70	30	23	41	39	45	36	52	0.63	−0.1	4	3,498	se.	23	sw.	6	12	12	6	4.4	0.0	0.0
Boise	2,739	79	87	27.11	29.94	−.03	62.5	+0.6	101	3	76	40	25	49	37	49	37	44	0.60	+0.1	4	2,984	nw.	19	nw.	8	13	11	6	4.2	0.0	0.0
Lewiston	757	40	48	29.13	29.93	−.05	64.5	+1.7	98	3	78	38	23	51	41	---	---	---	0.73	−0.2	7	1,987	e.	27	w.	6	15	5	10	4.5	0.0	0.0
Pocatello	4,477	60	68	25.45	29.90	−.06	61.3	+1.1	92	4	74	36	22	48	38	47	34	44	1.11	+0.3	7	5,322	se.	36	s.	4	12	12	6	4.1	T.	0.0
Pasco	416	5	33	---	---	---	64.2	---	98	3	80	35	7	49	47	---	---	45	0.04	---	2	5,394	sw.	---	---	---	11	13	6	---	0.0	0.0
Spokane	1,929	101	110	27.91	29.94	−.04	60.6	+1.4	91	3	72	40	23	49	36	50	40	55	1.05	+0.2	6	3,467	s.	24	nw.	20	7	13	10	5.3	0.0	0.0
Walla Walla	991	57	65	28.87	29.94	−.06	65.2	+1.4	95	3	76	38	23	54	35	52	42	46	0.98	0.0	5	2,708	s.	21	w.	18	12	13	5	4.3	0.0	0.0
Yakima	1,076	58	67	28.80	29.94	---	62.6	+1.5	95	3	76	38	24	50	39	51	42	52	0.23	−0.3	4	3,132	nw.	23	w.	20	15	8	7	4.1	0.0	0.0
North Pacific Coast Region							59.3	+1.0										74	3.02	+0.9										6.0		
North Head	211	11	56	29.80	30.02	−.01	57.0	+0.5	70	22	61	49	26	53	17	55	53	88	5.15	+2.2	16	9,227	n.	54	s.	29	7	10	13	6.2	0.0	0.0
Port Angeles	29	8	53	---	30.02	---	55.5	---	71	23	62	41	24	49	29	---	---	---	1.50	0.0	13	2,839	s.	26	w.	20	5	11	14	---	0.0	0.0
Seattle	125	215	250	29.86	29.99	−.02	59.2	+1.1	78	3	65	47	26	53	20	54	50	75	2.97	+1.2	11	4,895	s.	31	sw.	6	5	6	19	7.0	0.0	0.0
Tacoma	194	172	201	29.80	30.00	−.02	59.4	+2.1	81	3	66	43	22	52	28	---	---	---	2.67	+0.6	10	4,625	s.	33	sw.	6	2	10	18	7.5	0.0	0.0
Tatoosh Island	86	9	53	29.88	29.98	−.03	55.4	+2.4	72	23	59	48	8	52	24	53	52	89	7.97	+3.3	19	7,583	s.	42	s.	4	3	3	24	7.8	0.0	0.0
Medford	1,329	29	58	28.55	29.94	---	62.9	---	101	2	79	36	24	47	49	51	41	55	1.23	+0.7	6	3,170	nw.	28	nw.	6	17	8	5	3.2	0.0	0.0
Portland, Oreg.	153	68	106	29.84	30.00	−.03	62.8	+1.1	89	4	72	45	24	54	28	56	51	70	2.10	+0.1	10	3,241	nw.	18	ne.	22	7	7	16	6.5	0.0	0.0
Roseburg	510	75	99	29.44	29.99	−.03	61.9	−1.0	91	2	75	38	24	49	42	53	46	64	0.57	−0.7	7	2,476	n.	20	n.	22	14	11	5	3.7	0.0	0.0
Middle Pacific Coast Region							64.5	−0.3										57	0.13	−0.5										2.8		
Eureka	62	73	89	29.94	30.01	.00	55.6	−0.3	68	23	61	46	22	51	20	53	51	85	0.54	−0.5	5	3,279	nw.	32	n.	22	12	8	10	4.9	0.0	0.0
Red Bluff	330	5	58	29.52	29.87	−.06	72.0	−1.1	105	1	86	46	28	58	42	55	39	37	0.09	−0.7	1	4,015	s.	24	n.	22	22	7	1	2.3	0.0	0.0
Redding	722	20	34	---	---	---	68.6	---	103	1	78	49	28	60	34	---	---	32	T.	---	0	5,406	nw.	---	---	---	20	9	1	---	0.0	0.0
Sacramento	69	106	117	29.81	29.88	−.01	67.6	−1.7	98	13	82	47	9	53	42	56	48	56	T.	−0.4	0	5,338	s.	26	nw.	22	28	2	0	0.7	0.0	0.0
San Francisco	155	208	243	29.76	29.93	−.01	62.8	+1.9	86	30	70	52	1	55	30	56	51	73	T.	−0.4	0	4,882	w.	24	w.	17	12	17	1	3.6	0.0	0.0
San Jose	141	12	110	29.78	29.93	---	64.6	−0.1	91	21	78	45	24	52	39	---	---	---	T.	−0.4	0	3,826	nw.	22	sw.	14	19	8	3	2.6	0.0	0.0
South Pacific Coast Region							71.1	+1.3										60	0.10	−0.1										2.2		
Fresno	327	89	98	29.52	29.87	.00	72.2	−1.2	101	2	87	50	24	58	37	56	43	42	0.05	−0.2	1	4,457	nw.	24	nw.	7	24	6	0	1.1	0.0	0.0
Los Angeles	338	159	191	29.52	29.88	.00	71.5	+2.5	93	5	81	56	13	62	32	60	54	62	0.24	+0.1	2	2,932	w.	13	w.	25	22	5	3	2.2	0.0	0.0
San Diego	87	62	70	29.77	29.86	−.03	69.7	+2.6	86	21	76	59	11	64	24	64	61	76	T.	−0.1	0	3,959	nw.	20	w.	5	19	8	3	3.3	0.0	0.0
West Indies																																
San Juan, P. I.	82	9	54	29.84	29.93	---	80.6	+0.1	91	11	85	72	3	76	17	---	---	---	10.60	+4.7	22	6,648	e.	90	nw.	10	1	17	12	6.4	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	---	[1]29.83	---	79.6	−0.2	90	25	85	72	13	74	17	---	---	[1]87	11.09	+3.0	21	3,265	nw.	24	nw.	27	0	11	19	7.9	0.0	0.0
Cristobal	36	6	97	---	[1]29.83	---	81.6	+1.2	91	3	87	75	13	76	16	76	75	[1]83	8.24	−4.1	21	3,886	se.	24	nw.	28	1	9	20	7.8	0.0	0.0
Alaska																																
Fairbanks	455	11	44	---	[2]29.84	---	43.4	---	63	2	50	26	26	36	27	---	---	80	1.48	---	16	2,525	w.	14	sw.	22	1	4	25	---	T.	0.0
Juneau	80	11	50	[2]29.77	[2]29.77	---	50.8	---	69	7	57	36	16	45	23	48	45	84	9.37	---	21	3,183	s.	28	e.	30	4	8	18	7.6	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]29.95	[2]29.99	---	77.8	−0.4	84	21	82	71	7	74	12	72	69	77	2.69	+1.4	16	6,598	e.	25	e.	25	5	22	3	5.6	0.0	0.0

[1] Observations taken bihourly. [2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, September, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				55.3		63.2	47.5	75	34	4.23		0.0
Sydney, C. B. I	48	29.85	29.90	−0.11	57.8	+1.3	65.7	50.0	80	38	4.06	+0.78	0.0
Halifax, N. S	88	29.81	29.91	−.13	58.6	+1.0	66.6	50.6	82	41	6.95	+3.24	0.0
Yarmouth, N. S	65	29.83	29.90	−.15	57.7	+1.6	64.2	51.2	76	40	4.78	+1.17	0.0
Charlottetown, P. E. I	38	29.80	29.84	−.17	56.9	−0.4	62.7	51.1	76	42	3.76	+0.36	0.0
Chatham, N. B	28	29.80	29.83	−.17	55.4	0.0	64.2	46.7	85	33	3.86	+1.15	0.0
Father Point, Que	20	29.88	29.90	−.08	50.0	−0.4	57.4	42.7	70	31	4.83	+1.70	0.0
Quebec, Que	296	29.63	29.95	−.06	56.2	+1.1	63.4	49.0	83	35	6.51	+2.84	0.0
Doucet, Que	1,236				51.6		63.3	40.0	87	20	4.52		0.0
Montreal, Que	187	29.73	29.93	−.11	61.7	+3.3	69.2	54.2	90	42	7.44	+4.14	0.0
Ottawa, Ont	236	29.70	29.96	−.08	64.3	+6.9	75.7	53.0	102	39	5.70	+3.01	0.0
Kingston, Ont	285	29.67	29.98	−.06	64.4	+4.4	72.1	56.7	88	40	4.94	+2.14	0.0
Toronto, Ont	379	29.58	29.97	−.09	65.9	+6.9	75.4	56.4	96	42	2.18	−1.07	0.0
Cochrane, Ont	930				55.9		64.6	47.3	91	32	2.95		0.0
White River, Ont	1,244	28.62	29.92	−.06	55.5	+5.2	67.4	43.7	91	26	3.59	+0.82	0.0
London, Ont	808				65.8		77.1	54.5	95	32	3.57		0.0
Southampton, Ont	656	29.29	30.00	−.05	63.3	+5.8	73.3	53.4	92	36	4.20	+1.26	0.0
Parry Sound, Ont	688	28.28	29.96	−.07	61.7	+5.7	70.5	52.9	89	37	5.15	+1.48	0.0
Port Arthur, Ont	644	29.21	29.92	−.06	58.5	+6.3	66.8	50.2	78	41	5.46	+1.98	0.0
Winnipeg, Man	760	29.02	29.84	−.10	59.9	+7.4	70.3	49.6	96	33	3.23	+1.20	0.0
Minnedosa, Man	1,690	28.06	29.85	−.09	55.0	+4.5	65.9	44.1	93	29	1.54	+0.18	0.0
Le Pas, Man	860				51.6		60.5	42.8	83	32	5.09		0.0
Qu'Appelle, Sask	2,115	27.61	29.83	−.09	54.1	+3.0	65.3	42.9	90	31	1.25	−0.08	0.0
Moose Jaw, Sask	1,759				56.4		69.5	43.3	95	30	1.81		0.0
Swift Current, Sask	2,392	27.31	29.80	−.12	55.5	+2.4	69.7	41.2	96	32	2.35	+1.13	0.0
Medicine Hat, Alb	2,365	27.40	29.87	−.05	55.7	+0.7	67.6	43.8	92	30	1.76	+0.58	0.0
Calgary, Alb	3,428	26.21	29.86	−.06	50.8	+1.0	62.2	39.5	82	29	1.71	+0.35	0.0
Banff, Alb	4,521	25.32	29.89	−.04	47.2	+1.4	58.0	36.4	73	24	2.17	+0.50	0.0
Prince Albert, Sask	1,450	28.31	29.88	−.02	52.7	+4.3	62.6	42.9	84	30	2.66	+1.38	0.0
Battleford, Sask	1,592	28.11	29.83	−.07	52.7	+0.9	64.2	41.1	89	29	3.37	+2.12	0.0
Edmonton, Alb	2,150	27.55	29.83	−.07	50.2	+0.9	61.0	39.4	73	27	0.56	−0.77	0.0
Kamloops, B. C	1,262	28.62	29.90	−.07	57.0	−0.4	65.0	49.1	82	36	0.80	−0.45	0.0
Victoria, B. C	230	29.73	29.98	−.03	56.0	+1.2	61.5	50.5	69	46	2.28	+0.12	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20				53.9		59.6	48.3	68	42	12.21		0.0
Prince Rupert, B. C	170				53.4		59.1	47.8	64	42	8.10		0.0
Hamilton, Ber	151	29.96	30.12	+.05	80.8	+3.4	88.0	73.6	93	70	2.46	−4.05	0.0

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Sydney, C. B. I	48	29.96	30.01	+0.06	65.1	+1.8	74.0	56.2	85	46	6.52	+2.90	0.0
Halifax, N. S	88	29.89	29.99	+.03	66.8	+3.2	76.7	56.9	86	49	4.60	+0.25	0.0
Yarmouth, N. S	65	29.88	29.95	−.02	63.5	+3.3	71.8	55.2	79	48	3.60	−0.02	0.0
Charlottetown, P. E. I	38	29.88	29.92	−.02	66.4	+2.1	73.5	59.4	81	51	2.79	−0.95	0.0
Chatham, N. B	28	29.87	29.90	−.03	63.7	+0.5	74.0	53.4	86	44	3.38	−0.66	0.0
Father Point, Que	20	29.93	29.95	+.04	57.1	+1.5	65.0	49.2	76	44	1.92	−1.13	0.0
Doucet, Que	1,236				55.5		70.1	40.9	85	28	2.29		0.0
Kingston, Ont	285	29.71	30.01	+.03	69.1	+2.1	77.0	61.2	88	52	1.19	−1.19	0.0
Southampton, Ont	656	29.31	30.02	+.03	66.4	+2.6	76.0	56.8	89	44	1.96	−0.29	0.0
Medicine Hat, Alb	2,365	27.50	29.94	+.02	67.0	+1.3	82.3	51.8	97	36	0.22	−1.45	0.0
Calgary, Alb	3,428	26.34	29.96	+.04	61.3	+1.9	75.8	46.8	90	38	0.46	−1.68	0.0
Banff, Alb	4,521	25.45	29.98	+.07	57.0	+0.7	73.1	40.8	88	33	1.61	−0.92	0.0
Edmonton, Alb	2,150	27.70	29.96	+.04	60.1	+1.3	71.3	48.9	82	38	4.20	+2.07	0.0
Kamloops, B. C	1,262	28.69	29.95	+.04	68.8	+0.2	81.7	55.9	96	48	0.70	−0.39	0.0
Estevan Point, B. C	20				56.5		62.7	50.3	73	45	3.07		0.0
Prince Rupert, B. C	170				57.7		63.4	52.1	70	48	5.70		0.0
Hamilton, Ber	151	30.02	30.18	+.08	82.4	+2.8	89.8	75.1	95	69	3.76	−2.32	0.0

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GAP WINDS OF THE STRAIT OF JUAN DE FUCA

By Thomas R. Reed

[Weather Bureau office, San Francisco, Calif., July 17, 1931]

The easterly gales at the west end of the Strait of Juan de Fuca constitute one of the notable climatic eccentricities of the North American Continent. Indeed it may not be extravagant to claim for them a position unique among the winds of the world. The writer knows nothing in meteorological literature which describes their counterpart, although winds of similar type though less violent are common to many other localities. The type (for it is believed these winds belong to a distinct type) undoubtedly reaches its culmination at or near Cape Flattery, Wash., at the entrance to the Strait of Juan de Fuca. This strait affords the principal sea-level egress for air evicted by gravity from the drainage basin of Puget and Washington Sounds. It lies in a nearly east-west direction and is about 75 miles long. At its western end it opens into the Pacific Ocean, and at its eastern end into Puget and Washington Sounds. It is walled on the north by the mountains of Vancouver Island and on the south by the Olympic Mountains. The basin into which the strait leads is flanked on the east by the Cascade Range and on the west by the Coast Range, including the Olympics.

Fortunately for the needs of investigation, the Weather Bureau is provided with ample observational data at this point, a fully equipped station having been maintained at Tatoosh Island, near the cape, for many years. The exposure of the wind instruments is good. They are located 113 feet above mean sea-level at a point where the island reaches a height of 80 feet above the sea. The island is described in Henry's "Climatology of the United States" as "a rock standing 75 to 100 feet above the ocean, three-fourths of a mile directly west of Cape Flattery, and at the mouth of the Strait of Juan de Fuca. With a rolling surface, it covers an area of a little less than 17 acres. The sides are precipitous. There are no trees or buildings that in any way interfere with the exposure of the instruments." The Weather Bureau installation is in the center of the island.

The frequency of easterly gales at Tatoosh Island is recognized by forecasters of the Weather Bureau, but it is doubtful if many of them have noted the individual and extraordinary character of these gales. Desiring to secure information in this regard, the writer appealed a few years ago to the Weather Bureau official at Tatoosh Island for a statement of the total number of easterly winds of 40 miles per hour or over which had been recorded there in the 5-year period, 1923–1927, inclusive. His answer stated that of 450 gales, all directions considered, which were recorded during that period, 219 were from an easterly quarter. Eleven of these gales were from the northeast, and three from the southeast. The remaining 205 were due east, an average of 1 in every 9 days for the 5-year period. When it is realized that the vast majority of these winds occurred during the winter season, the percentage of frequency for that time of year becomes more impressive still. The circumstance, however, which makes them especially worthy of note is not their frequency but their origin. They are not, properly speaking, gradient winds. That is to say, they do not approximate even remotely as a rule the air-flow requisite to balance the pressure gradient. Neither can they be classed as katabatic.

In support of the assertion that they are not gradient winds, considerable evidence has been adduced. Seventy-five cases have been considered. They include all easterly gales of 50 m. p. h., or over, which occurred during the inclusive period 1924–1927. Winds for 1923 were dropped out of the investigation because of the inadequacy of information touching the pressure situation at sea prior to 1924, information which could not be ignored in a discussion of coastal winds without casting doubt on the conclusions.

Also, it was decided to eliminate from consideration velocities of less than 50 m. p. h., since this economy of material would make the data more manageable without sacrificing any facts essential to correct deductions. Furthermore, it should be noted that all velocities are from records of the 4-cup anemometer; hence the adoption of 50 m. p. h. as the minimum to be considered really eliminates only winds of less than actual gale force, since the true velocity in miles per hour corresponding to 50 miles indicated on the 4-cup anemometer is 39.7 miles, or approximately the minimum that could be classed as a gale in Beaufort's terminology. It should be explained further that the 75 cases coming under this classification refer to the number of dates involved, not the number of individual gales; in several cases the gales extended over a period of two or more days, while in others they occurred on a single night both before and after midnight, thus requiring their entry as of two calendar days.

First let the statement that these winds are not ordinary pressure gradient phenomena be considered. While casual inspection of the synoptic charts for almost any of the dates involved would lead to this assumption, the writer sought to eliminate any grounds for contention by preparing a detailed table of pertinent data covering each instance. The table gave a full list of easterly gales at Tatoosh Island with dates of occurrence and set forth adjacent thereto maximum wind velocities and directions on concurrent dates at the four Weather Bureau stations nearest to Tatoosh, namely, Port Angeles situated on the strait about 63 miles eastsoutheast of Tatoosh; Seattle and Tacoma situated on the east side of

Puget Sound about 124 miles and 133 miles, respectively, southeast of Tatoosh; and North Head situated on a promontory of the coast 150 miles south of Tatoosh. Maximum winds recorded in the log of the Swiftsure Bank Lightship, anchored about 15 miles northwest of Tatoosh, also formed a part of the table.

No rigid inspection of the statistics was needed to convince one of the peculiar nature of Tatoosh winds, or to dissociate them from essentially pressure gradient phenomena. First were considered the maximum winds which occurred over Puget Sound on the dates when easterly gales were registered at Tatoosh. In only three cases did these winds reach gale force (40 m. p. h.) at Tacoma, and in only five at Seattle. Taking 50 miles as representing a gale for these stations, as was done for Tatoosh, the contrast was more striking yet. Only 1 such gale occurred at Tacoma and only 2 at Seattle, as against 75 at Tatoosh. None was recorded at Port Angeles. The mean velocity of the 75 maximum winds at Tatoosh was 60 m. p. h., at Tacoma 20 m. p. h., at Seattle 23 m. p. h., and at Port Angeles 16 m. p. h.

Significant as these comparisons are, they are rendered still more so when directions are considered. All the gales at Tatoosh were due east. If they were strictly gradient winds it would be natural to look for predominant easterly components in the winds occurring simultaneously over the region from which they were directly supplied, or which might be considered as their immediate source. This emphatically was not so. At Tacoma only 11 per cent of the maximum velocities had any easterly component whatever, at Seattle only 37 per cent, and at Port Angeles, where none might expect the greatest preponderance of due-east directions because of its location at the eastern end of the identical strait on which Tatoosh is situated, only 47 per cent showed an easterly component, while there were numerous cases of southwesterly directions and a few from the northwest. Of the two blows at Seattle which exceeded 50 m. p. h., the direction in one case was southwest and the other south. The one blow at Tacoma which exceeded 50 m. p. h. was from the southwest. On the same dates the maximum wind at Port Angeles was 24 m. p. h. southwest and 24 m. p. h. north, respectively.

These facts certainly disposed of any presumption that the Tatoosh gales are dependent on a general and marked pressure gradient over the immediate hinterland, if that term may be used to delimit the basin which incloses the waters of Puget and Washington Sounds. However, lest any doubt lurk on this point (the vagaries of surface wind movement over rugged country and landlocked waters being freely admitted) examination was made of the actual pressure gradient between the interior and the coast on the dates in question. The mean pressure difference at 5 p. m. between Seattle and Tatoosh, an air-line distance of about 124 miles, for the 75 days on which easterly gales occurred at the latter station, was 0.09 inch. This to be sure did not represent pressure differences computed for the exact moments at which extreme velocities were reached at Tatoosh. The labor involved in such research was too great to impose on the men employed in meteorological duties there and at Seattle. It did, nevertheless, furnish a serviceable approximation, the convincing nature of which was enhanced by considering individual cases. Thus, for example, three instances were found of no pressure difference between the two stations, and four where the gradient was negative; that is, *higher at Tatoosh than at Seattle.* While the wind had subsided to some extent in every case, and in two had undergone radical change in direction at 5 p. m. when the pressure observations were made, five of the seven instances were very remarkable, the wind continuing from an easterly quarter at Tatoosh at a velocity which ranged between 18 and 38 m. p. h. Here, indeed, is interesting material for the student of pressure-gradient phenomena.

The foregoing, while disposing of any assumption of an inland pressure gradient steep enough to account in itself for the easterly gales at Tatoosh, takes no cognizance of what may have been the pressure situation at sea at such times. The query naturally arises: Should we expect to find a pressure gradient offshore steep enough to account for the extraordinary gale phenomena at the cape? The answer is in the affirmative only if we consider the gales under discussion as belonging to a distinct type—an orographic or so-called bottle-neck type. An investigation was made of the barometric pressure over an extensive network of stations in the Pacific Northwest at the approximate time the gales listed were in progress. In most cases data secured from 5 p. m. (Pacific time) observations sufficed. In a few cases, however, 5 a. m. data were employed. Pressure data for numerous points at sea were obtained by interpolation from manuscript weather charts on file at the San Francisco office of the Weather Bureau, prepared from observations taken on shipboard a trifle earlier than at the land stations, viz, 4 a. m. or 4 p. m., Pacific time.

A cursory examination of these data confirmed the natural expectation of finding conditions best for an easterly gale at Tatoosh when the pressure is abnormally high to the northeast and low to the southwest. Closer inspection, however, revealed the inadequacy of pressure gradients therein to account per se for the velocities which actually occurred, even in the relatively few instances which called for winds of gale force over the open sea. That the pressure situation both on land and at sea contributed indirectly to the gales at Tatoosh is not questioned; that it did so in such a way as to entitle them to classification as gradient winds is denied.

In support of this denial there is additional testimony. A composite isobaric chart was constructed, presenting means of the pressure data referred to above. This chart, while confirming the observation that high pressure to the northeast and low pressure to the southwest of Tatoosh are the ideal conditions for easterly blows at that point, also demonstrated by the very weakness of the composite gradient the fact that such blows may occur under the most diverse individual conditions of pressure distribution. In other words, it appeared that easterly gales may occur at Tatoosh with the lowest pressure in any of the three sectors, north, south, or west. There were 35 dates when the lowest pressure was to the southwest of Tatoosh, 27 when the lowest pressure was to the northwest, 8 when it was lowest at Eureka, Calif., and 1 when it was lowest at Kamloops, British Columbia. The preparation of charts more closely synchronized with the time of occurrence of the peak winds might change these figures somewhat; nevertheless it is believed the ratios would remain substantially the same.

Comparison of winds at the two nearest coastal observation points was made: At Estevan, located on the southwest side of Vancouver Island 110 miles northwest of Tatoosh, and at North Head, situated on the Washington coast 150 miles south of Tatoosh. Maximum wind data were not obtainable for Estevan, but current wind data reported at the time of the regular 5 a. m. and 5 p. m. observations were compiled from entries on the pencil charts at San Francisco. These showed 14 instances of a calm at Estevan when the wind was blowing

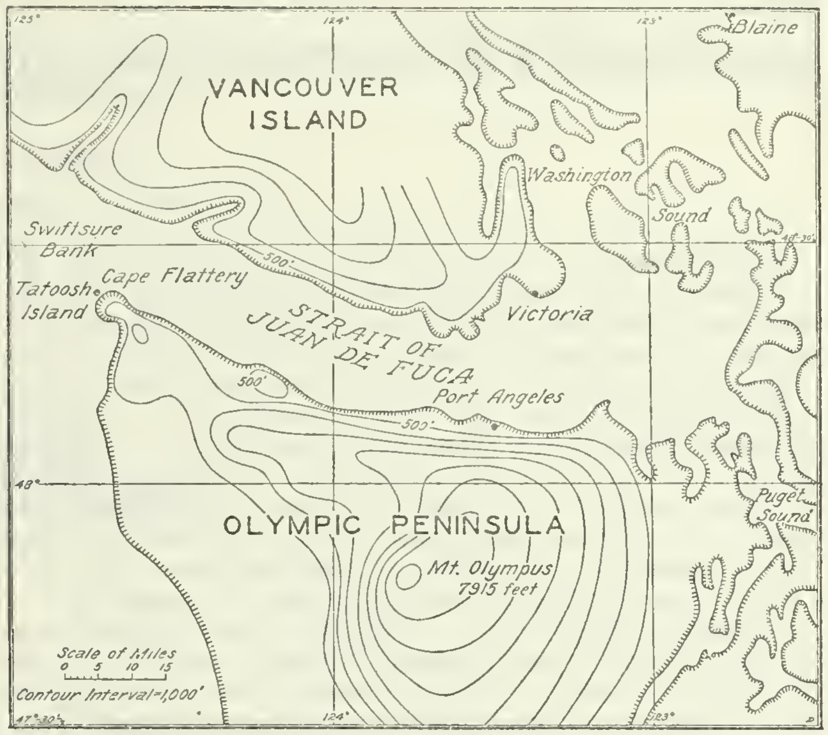
out of the strait at Tatoosh Island at a rate of anywhere from 18 to 76 miles per hour. In only 3 out of 14 cases was the velocity at Tatoosh less than 40 m. p. h. Significant, too, was the great variety of directions recorded at Estevan at other times. In the 71 cases investigated (Estevan reports were missing on 4 dates) all but 6 showed due east winds at Tatoosh, and an average velocity for all of 38 m. p. h. Simultaneously, Estevan showed, in addition to the 14 calms mentioned, numerous cases of winds from the north, northwest, and west, with a mean velocity of 8 m. p. h.

Passing from the coast nortwest of Tatoosh to that lying south of it, wind figures for North Head were examined. Here maximum velocities were available. North Head offers the best exposure for the registration of gradient winds of any of the stations for which data are submitted, as it is situated on a promontory of the southern Washington coast 250 feet above the sea. Moreover, this station lies in the same climatic zone as Tatoosh and storms that affect one usually affect both. It is recognized that orographic influences tend to accentuate the velocity of the wind at North Head, and that many more gales are recorded there than would be found in that vicinity at sea. This is not only a logical inference, but one frequently confirmed by radiographic weather reports from ships in the offing. Nevertheless North Head offers as good an exposure for the registration of gradient winds, both direction and velocity considered, as could be found in that section of the coast. It is especially valuable in connection with this study, as storms that produce southerly gales at Tatoosh are almost certain to produce as high or higher velocities at North Head. The percentage of gale frequency is the same for both. During the period 1923–1927 inclusive there were 450 gales of all directions at Tatoosh and 440 at North Head. Gales at North Head as a rule are obviously related to the pressure gradient at sea, while a substantial percentage of those at Tatoosh are not. Of the 75 dates on which easterly gales of 50 m. p. h. or over were recorded at Tatoosh, the maximum wind at North Head was from the east on only 32, with a mean velocity for the 32 occasions of 27 m. p. h. The direction on most of the other dates was from the south. The mean velocity at North Head for all directions was 39 m. p. h.

A survey of the foregoing evidence, while disposing of the inference that the Tatoosh gales are pressure gradient phenomena in the strict sense of that term, leaves untouched the question of their relation to the horizontal temperature gradient. Can they be classed as katabatic? Almost as many easterly gales were recorded at Tatoosh with the temperature above normal over Puget Sound as with the temperature below normal. Nor does it appear absolutely necessary to have the air in the interior colder than at sea, as witness the blows of June 25, 1925, and September 18, 1927. On the latter date the highest temperature of record for that time of year, 76°, occurred at Tatoosh, and even higher temperatures were recorded in the interior; while on the former date still more extreme conditions prevailed, the highest temperatures ever recorded there being reached at both Seattle and Tacoma.

The vagaries of wind direction and velocity introduced by irregularities in the terrain are admitted. It may be suggested therefore, that easterly gales at Tatoosh are frequently of a quite local character and do not reflect wind conditions even a few miles out in the channel. The records of the Swiftsure Bank Lightship were studied and gave a strong indorsement to the reliability of Tatoosh data as representing the general wind movement out of the strait. These records, though not obtained by instrumental means, are believed to represent very conservative estimates. In the opinion of the lightship master they are much more likely to be underestimates than overestimates of wind force. Moreover, they actually represent only the highest force noted at observations taken at two hour intervals, i. e., at 2, 4, 6, 8, etc., o'clock. Velocities between times may have been higher although allowed to pass without note. With this in mind it was recognized that the wind movement near the middle entrance of the strait where the lightship is anchored, fully 15 miles northwest of Tatoosh, agreed remarkably well with the easterly gale data for Tatoosh itself. There were 42 days when the force (Beaufort scale) exceeded 7, and the average force for the 75 cases was between 7 and 8. The winds, therefore, are not a vagary peculiar to the sides of the strait, but obtain in mid-channel as well.

In seeking to account for this phenomenon, obviously we must look elsewhere than to a marked pressure or temperature gradient for the explanation. That the



winds are fundamentally due to difference in air pressure between the interior regions and the sea is evident, although this difference may not be expressed as a pressure gradient in the vicinity of Tatoosh or the Strait of Juan de Fuca. Admitting that the pressure difference exists, however, as between the air mass over the interior and that at sea, the peculiar manner of outflow arising from such difference rather that the amount of the difference must account very largely for the extraordinary rate of movement of the air at and near the point of ejection. It must be peculiarly an orographic phenomenon, originating in a pressure inequality and varying as the degree of such inequality, but deriving its remarkable velocity from the converging sides of the channel through which it makes its way.

The physiographical conditions for the production of such winds at Tatoosh are ideal. The drainage basin which includes Puget and Washington Sounds furnishes the reservoir for a vast body of air of nearly homogeneous density. The converging terrestrial walls flanking the Strait of Juan de Fuca constitute the funnel through which the bulk of this air must flow at the behest of

lower pressure at sea. The contracting channel acting like a Venturi tube increases the speed of the flow until by the time the gap at the point of ejection is reached extraordinary velocities are attained.

Winds similar in type if not in strength are to be found wherever the character of the terrain restricts to some gap or gorge the passage of air from regions of higher to regions of lower pressure. They are a common orographic phenomenon of the moving air. For this reason some special term to define and describe them seems to be demanded. Maj. E. H. Bowie has suggested the name "bottleneck winds." "Funnel winds" was used some years ago by Mr. S. L. Trotter in a paper dealing with marked incongruities in gale velocities at certain observation points on the Atlantic coast.[1] The writer has already employed the term "orographic" in referring to such winds, although in the opinion of some it is open to objection as being too general. "Gap winds" is sufficiently specific and is favored by at least one meteorologist of eminence.[2] "Orographic" would, it is true, apply to a wider variety of winds than any of the other terms suggested. It would describe winds which increase in velocity by passing *over* a mountain barrier equally as well as those which increase in velocity by passing *through* a gap or gorge. Both phenomena deserve appropriate nomenclature. They are so characteristic of the moving air as to have become a commonplace of airway weather observations in mountain districts. They occur in such regions with a consistency which would be surprising if the cause were less obvious. Orographic winds, whether of the gorge, gap, or ridge variety, are obeying in principle if not in detail the law exhibited in the functioning of a wind tunnel or a Venturi tube. In the gorge, three sides of a Venturi are roughly represented; in the ridge but one. But the constriction affecting the flow operates effectively, though in varying degree, in all cases. Indeed the term "Venturi winds" may be offered without doing violence to logic.

[1] Local Peculiarities of Wind Velocity and Movement Atlantic Seaboard—Eastport, Me., to Jacksonville, Fla., by Spencer Lee Trotter. Page 634, vol. 48, Monthly Weather Review.

[2] In a marginal comment on the author's manuscript, Prof. W. J. Humphreys wrote. "Orographic winds is not good—it is too general. Why not 'Gap winds?' That is what they are. I have a vague impression that this term has been used."

SOME EFFECTS OF CALIFORNIA MOUNTAIN BARRIERS ON UPPER AIR WINDS AND SEA-LEVEL ISOBARS

By Delbert M. Little

[Weather Bureau Airport Station, Okland, Calif., August 17, 1931]

The intensive weather service for airways, with its numerous hourly and three-hourly reports and six-hourly upper-air data, has provided an opportunity for meteorologists to examine in great detail the day to day meteorological situations. Accurate barometer readings and upper-air wind data are most important to a proper understanding of the situations portrayed by synoptic charts. Mountain barriers play an important though invisible part on the weather charts, and it therefore seems proper that some effects of these barriers on barometric pressure and winds, as deduced from the California 3-hourly airways weather charts, be presented.

Upper-air wind data for California are obtained from the following 11 pilot balloon stations, each in or near the State: Redding, Oakland, Fresno, Lebec, Los Angeles, San Diego, March Field (Riverside), Santa Maria, Reno, Nev., Yuma, Ariz., and Medford, Oreg. Of these, 7 are Weather Bureau stations, 2 Signal Corps stations, 1 a Navy station, and 1 privately maintained but cooperating with the Weather Bureau.

Of the California 3-hourly reporting stations, 15 use the mercurial barometer and are located in or just beyond the State at the following places: Eureka, Redding, Oakland, San Jose, Fresno, Bakersfield, Lebec, Estero, Los Angeles, San Diego, March Field (Riverside), Tonopah, Nev., Reno, Nev., Phoenix, Ariz., and Medford, Oreg. Reports also are received from a number of stations to the east and north of the last four named. In addition, there are 30 stations in California reporting pressure from aneroid barometers. Readings from aneroid barometers at first were of little value, (*a*) because of their uncertain height above sea level and (*b*) because of slowly changing instrumental errors. Eventually a plan was worked out to establish arbitrary corrections, to be revised from time to time, for reduction to sea level of all readings from aneroid barometers at low-elevation stations, i. e., stations less than 400 feet above sea level. Each arbitrary correction was based upon the departure of the aneroid reading from an interpolated value secured from the regular 8 a. m. and 8 p. m. seventy-fifth meridian time charts at times when "flat" pressure maps are evident and *no strong upper air winds prevailed.*

For each aneroid barometer at a high elevation a reduction table was secured from a Weather Bureau station whose elevation was approximately the same as the aneroid to be reduced. Then a small arbitrary correction was determined by the method of interpolation described above in order to fit the aneroid reading very closely to the reduction table. Arbitrary corrections are changed by a new interpolated value from time to time, thus very nearly eliminating any error due to seasonal march of temperature or changed instrumental error. It is safe to say that ordinarily the accuracy of these aneroid reductions is to within 0.03 inch of the true sea-level pressure values. With one-third of the barometers of the mercurial type well distributed over the State, it is not at all difficult to detect errors in and adjust readings of the aneroids at other stations in the network.

Approximately 50 airway and off-airway reports are entered every three hours on a base map printed from a plate of the Stanford relief model of California. The valleys and mountain ranges stand out in striking contrast to aid the meteorologist in determining the effect of the terrain on weather, as well as to visually aid pilots seeking advice as to the weather over the airway. Some of the salient facts noted on the synoptic maps are as follows:

1. Exceptionally steep pressure gradients at times prevail over mountain barriers and the isobars very frequently follow the mountains in a general way, but not exactly parallel to elevation contours.

2. In cases of extreme pressure gradients, the upper air winds immediately over the barriers are of strong to hurricane force and at nearly *right angles* to the sea-level isobars along the mountains.

3. The surface barometric pressure is increased on the windward side and decreased on the leeward side of mountain barriers in comparison with pressures reported at considerable distances from the mountains.

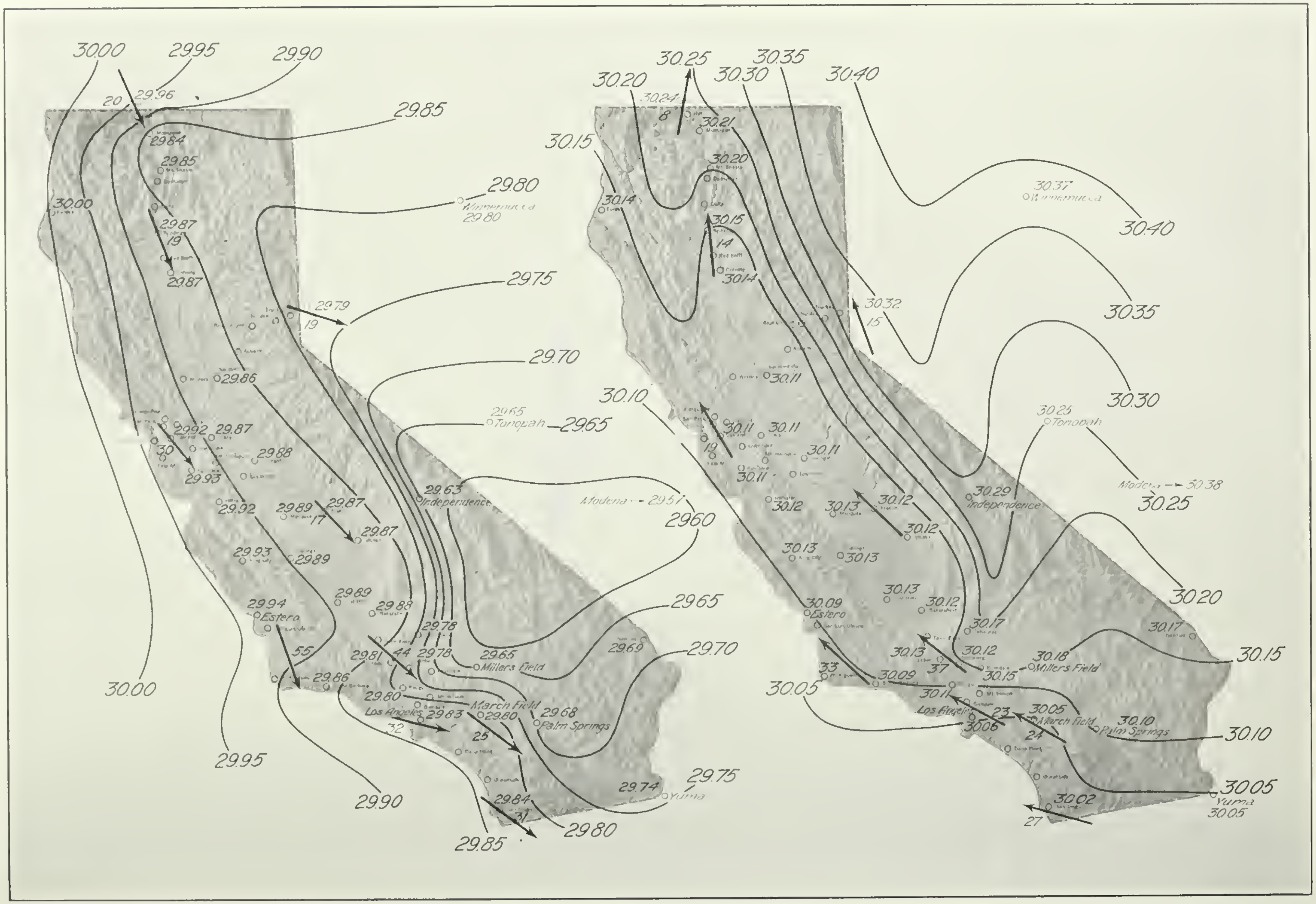


FIGURE 1.—Composite sea-level pressure maps for nine cases of extreme low pressure at Independence, Calif., in relation to Fresno, Calif., and nine cases of extreme high pressure at Independence, Calif., in relation to Fresno, Calif., during the period November, 1930, to March, 1931, with average upper air winds at 6,500 feet to 8,000 feet above sea level

4. A trough of low pressure forms rapidly in the lee of a mountain barrier as upper air winds increase in velocity in crossing the barrier.

5. The trough of low pressure on the leeward side of the mountain barrier persists for many hours after the center of the depression has passed away from the vicinity of the barrier.

Some of the best examples of extreme pressure gradients over mountain barriers in the United States are found in the Rocky Mountain States. Extreme differences in the temperatures of the air masses on the opposite sides of these mountain barriers often largely account for the differences in the computed sea-level air pressures. However, there are many cases where differences in the temperatures of the two air masses do not wholly account for the extreme pressure gradients over the mountain barriers. This was particularly noted on the California airways weather charts when, during the late fall and winter seasons, temperature differences on the slopes of the Sierra Nevada and Tehachapi ranges often were small.

Many meteorologists are familiar with the occasional large differences in the reduced (to sea-level) barometric pressures between Fresno to the west of the Sierra Nevada and Independence to the east. Some have been inclined to disregard the Independence barometer reading on the assumption that it was in error, or was faulty due to abnormal temperature. The writer studied the Independence barograph traces from November, 1930, to April, 1931, and checked them against the observed mercurial barometer readings and the reductions to sea level. Many unimportant differences in the mean temperature argument between Independence and Fresno were noted. It was found that personal errors do not enter into the reduced (to sea-level) barometric data for Independence and that the data are quite as accurate as those received from any other Plateau station, yet they appear to be more erratic. The elevation of Independence is 3,957 feet, which is somewhat lower than the average Plateau station.

Nine cases of extreme low pressure and nine cases of extreme high pressure at Independence in relation to Fresno were selected from the charts of November, 1930, to March, 1931, inclusive. Composite pressure maps for the nine cases of each type of pressure distribution were prepared as shown on Figure 1. All of the aneroid and mercurial sea-level barometric data received from the airways reports were used. Isobars were drawn for each .05 inch of pressure to bring out the pressure gradients over California in more detail. From inspection of the upper air winds shown on the maps for the several days selected, it was evident that northwest and west-northwest winds were associated with relatively low pressure at Independence, and southeast or east-southeast winds with relatively high pressure. The average velocity and direction of the winds at 6,500 to 8,000 feet above sea level were plotted on each map in Figure 1.

In order to determine whether there was a relation between the velocity of the upper air winds and the pressure gradient between Independence and Fresno, the upper air wind data at Lebec (elevation above sea level, 3,576 feet) were selected as being most typical. The upper air winds for Fresno were not used because of the topographic or shielding effect of the Sierra Nevada. East to southeast winds were selected because of the absence of stormy weather during their prevalence and consequent completeness of the upper air data. Resultant velocities were computed for each minute of observation for 45 balloon runs with east to southeast winds of moderate to gale velocities at Lebec during November, 1930, to March, 1931. The graph of these resultant velocities at Lebec indicates that the winds reached the highest velocities at altitudes ranging between 5,700 and 7,400 feet above sea level, and attained from the fourth to sixth minutes of the balloon run. The individual data for these altitudes, then, should be the most significant in determining whether a relation exists between east to southeast wind velocities over the mountain barrier and the high pressure at Independence. Ninety-five cases during the period referred to were used in which the Independence sea-level pressure was higher than that at Fresno and the upper air winds from the fourth to the sixth minute observation at Lebec were from the east to southeast. Using these selected data, the table of averages shows that with increasing velocity of the wind the pressure becomes higher at Independence than at Fresno.

Average velocities in miles per hour of east and southeast winds for the fourth to sixth minutes of balloon runs at Lebec, Calif., during November 1930, to March 1931

Sea-level barometer at Independence higher than at Fresno by—	Difference in mean temperature argument Independence and Fresno	
	84 cases of 0° to 13° F.	11 cases of over 13° F.
	Miles per hour	*Miles per hour*
0.04 to 0.06 inch	14	13
0.07 to 0.11 inch	23	15
0.12 to 0.17 inch	27	22
Over 0.17 inch	35	20

We are not in the habit of thinking that winds cause a pressure gradient but rather that a pressure gradient causes winds. However, when an air mass is flowing over a mountain barrier, undoubtedly there is a tendancy toward compression on the windward side and an expansion on the leeward side of the mountain. An abnormal pressure gradient in the vicinity of the barrier results. It might be argued that the air is free to rise vertically and a compression could not exist, but there is undoubtedly a restraining force due to the increased momentum of successive layers of air involved. It might also be argued that the data in the table could be transposed to prove that the winds are gradient winds caused solely by the pressure gradient. If this is the case, then it is not apparent how the belt of slightly excessive pressure along the east side of the Sierra Nevada is maintained for several days at a time, except by the explanation of wind action against the mountain barrier, i. e., compression. (See the map at the right in fig. 1.)

A similar phenomenon occurs along the shore line of California, Oregon, and Washington when on-shore winds prevail.[1] It is at times particularly marked because there is no coastal plain, and fairly steep mountain ranges parallel the shore line from southern California to the Canadian border. As long as the winds in the lower layers of the atmosphere are southeasterly the phenomenon is not apparent on our maps, the "refrac-

[1] Sir Napier Shaw, Manual of Meterology, Vol. IV (Part IV) pages 98–99.

There is moreover another reason why a station on the coast presents a complication in the relation of observed wind to gradient which may be operative in windy weather when the local gradient of temperature is not very marked. This second reason is the dynamical effect upon the stream of air due to the sudden transition between a surface with a comparatively low coefficient of eddy viscosity, such as the sea, and one with a comparatively high coefficient, such as a land surface, particularly a hilly or rugged land surface. This change must probably be represented by a sudden transition of pressure in the surface layers which produces a "refraction" of the isobaric lines on crossing the coast. * * * The mere addition of the volume of the land to that of the air which passes over it must produce some increase of the pressure at sea level.

tion" probably being slightly reversed with winds off shore at an acute angle, but as soon as a cyclone in the north approaches the Canadian coast and the winds veer, the phenomenon appears on our airways maps and becomes more marked as the winds veer to westsouthwesterly. This "refraction" of the isobaric lines therefore gives us immediately knowledge that the winds are veering during periods of stormy weather with the cyclone to the north and usually with upper air data missing. This is a distinct aid in forecasting airway weather conditions for short periods in advance.

Compression effect on the windward side of a mountain barrier does not fully explain its counterpart, namely the barometric troughs on the leeward side. In order to have a better understanding of the entire phenomenon, it would be of advantage to know, in a general way, how air flows over a mountain barrier. With single theodolite balloon runs, it is not possible to determine, from the individual runs at Lebec, the amount of vertical component in the lower levels and whether at some average

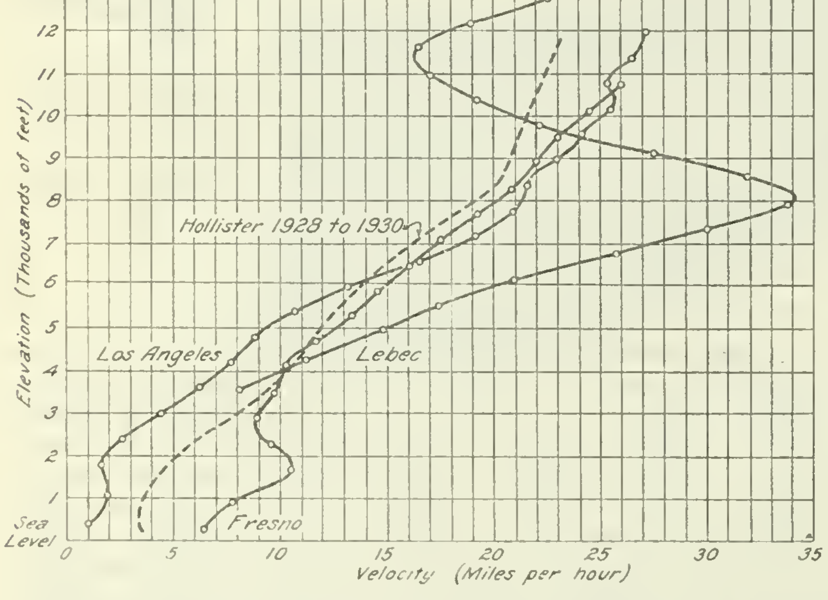


FIGURE 2.—Resultant velocities of north northwest and northwest winds over Fresno, Lebec, and Los Angeles, Calif., during the period November, 1930, to March, 1931, inclusive. Resultants computed from 71 to 85 runs nearly simultaneously, at the three stations with data nearly complete to the highest altitudes

altitude there ceases to be a vertical component to the winds over the mountain barrier. However, some interesting evidence bearing on this question has been obtained by comparison of graphs of resultant velocities for west-northwest to north-northwest winds at Lebec and surrounding pilot-balloon stations.

Graphs of resultant velocities over Fresno, Lebec, and Los Angeles for all cases of west-northwest to north-northwest winds over central and southern California during November, 1930, to March, 1931, inclusive, were prepared (see figure 2), from data which were nearly complete to 12,000 feet above sea level. The resultant directions were, of course, northwest to north-northwest or nearly parallel to a line running through Fresno, Lebec, and Los Angeles. The graph for Lebec shows extreme velocities at about 8,000 feet above sea level. A decided change in slope of the curve for Los Angeles at about 8,000 feet above sea level, and a faint bulge in the curve for Fresno at about the same elevation stand out prominently. A similar resultant velocity graph for Santa Maria with less data available shows a decided change in the slope of the curve at slightly above 8,000 feet. Data from short balloon runs were discarded in computing these resultants and the data are 90 per cent complete at the highest levels.

To prove that the changes in the slopes of curves at 8,000 feet were not peculiar to the period selected, 188 cases of north to west-northwest winds over Hollister, Calif., from October, 1928, to September, 1930, were used and the resultants computed. The data were 95 per cent complete to the highest level, all short runs being discarded. A decided change in slope of the curve for Hollister at 8,000 feet above sea level is shown. From these graphs it appears that practically all topographical retardation in velocity of northwest winds over the Tehachapi and coastal ranges of mountains has been eliminated at 8,000 feet above sea level.

It is important to note that only two or three peaks in these ranges of mountains extend to 8,000 feet.

It should not be assumed that most of the air when moving southeastward over the San Joaquin Valley below the mountain barriers, is forced upward and crosses the Tehachapi Mountains. This is not the case, for the balloon runs for Fresno show that on numerous occasions a large anticlockwise eddy, with vertical axis, at elevations averaging between 2,000 and 5,000 feet above sea level while winds near the surface and above these altitudes are moderate to strong north to northwesterly. This great valley eddy is not always marked by winds of opposite direction at those levels over Fresno, but its effect on often noted in the marked decrease in velocity of north to northwest winds at those levels. This is important from an aircraft pilot's standpoint as he may often escape the full effect of northwest head winds by flying at about 3,000 feet along the eastern side of the San Joaquin Valley.

The resultant velocities of northwesterly winds at elevations between 6,500 and 11,000 feet above sea level over Fresno are approximately equal to the resultant velocities at corresponding elevations over Los Angeles. The resultant velocities for similar winds over Lebec, in the Tehachapi Mountains, do not show this similarity because of the extreme velocities at 8,000 feet above sea level. A somewhat striking chart of the extreme velocities of the northwest winds is obtained by plotting a series of individual balloon runs on a single graph. (See fig. 3.) The extreme velocities of air flowing over a mountain barrier may be explained by assuming that the velocity increases as a considerable portion of the air passes through a restricted outlet. Part of the abnormal velocities observed at this level may be fictitious and due to insufficient rise of the balloon on entering the rapidly-moving air stream, but if there is any upward vertical component to the air, which seems possible because Lebec is on the north slope of the range, the error would be minimized.

Similar graphs of the resultant velocities of southwesterly winds over Fresno and Reno (see fig. 4) show the maximum velocities over the Sierra Nevada, as indicated by the Reno graph, at about 11,500 feet above sea level. The average height of the Sierra Nevada west of Reno is approximately 3,000 feet greater than the average height of the Tehachapi. This accounts for the greater height above sea level of the extreme velocities observed over the mountain barrier at Reno than over that at Lebec.

The increased velocity of the free air, immediately over mountain barriers, then, no doubt causes decreased pressure on the leeward side of the barriers. This phenomenon may be said to be similar to the decreased pressure on the upper surface of an airfoil in flight,[2] the mountain

[2] For an excellent explanation of this phenomenon see "A Philosophy of Lift" by H. F. Lusk, MS. published in United States Air Services, March, 1931.

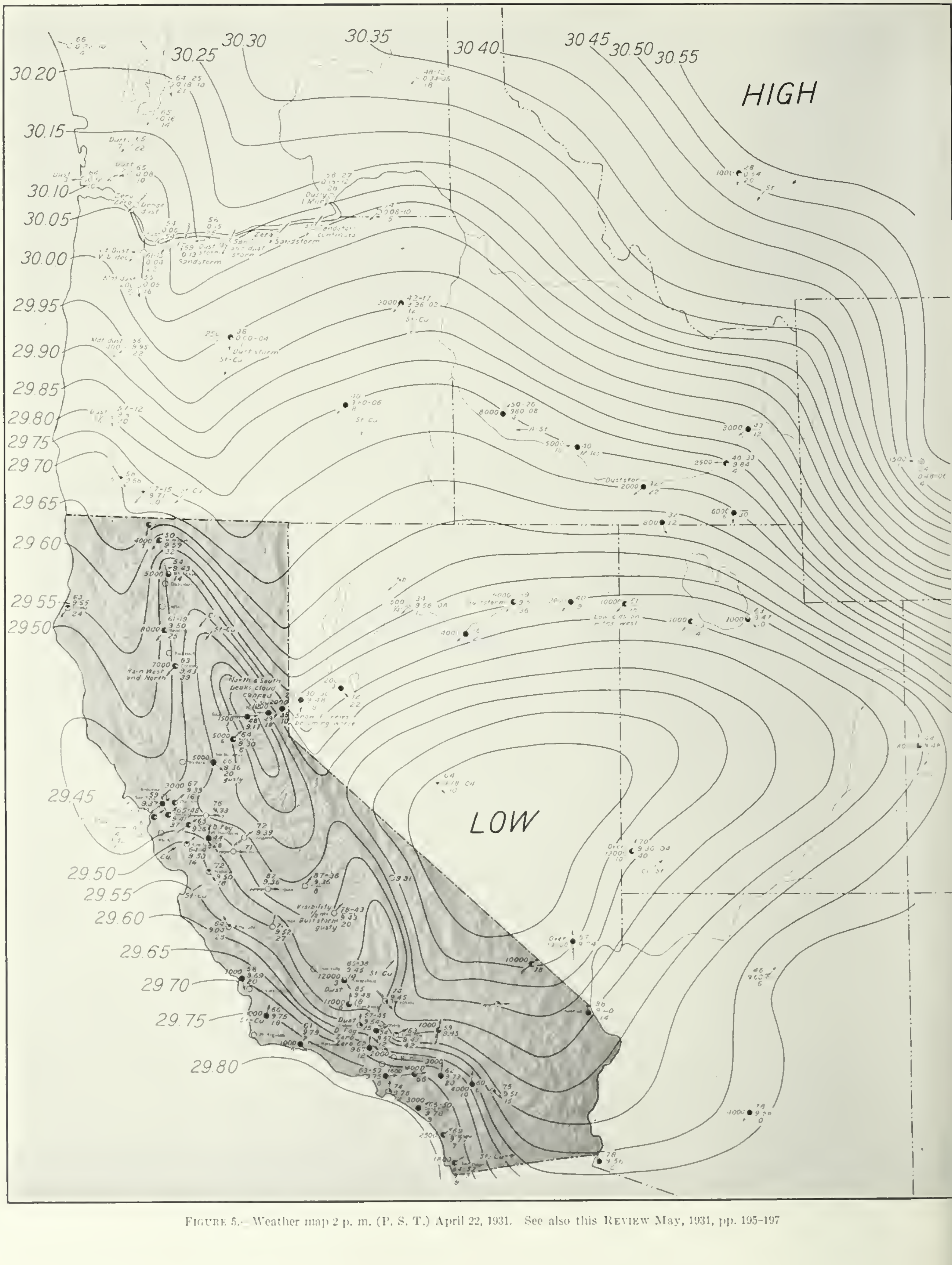


FIGURE 5.—Weather map 2 p. m. (P. S. T.) April 22, 1931. See also this REVIEW May, 1931, pp. 195–197

range being roughly similar to the upper surface of an airfoil.

To illustrate the phenomenon described, a map is presented (see fig. 5), on which all of the data from the airways weather reports are used. Isobars are drawn for

There is still another interesting phenomenon observed in many of the Lebec runs which is indicated on the Lebec northwest wind resultant curve when it is compared with those of Fresno and Los Angeles. It should be kept in mind that the balloon runs used to compute the three

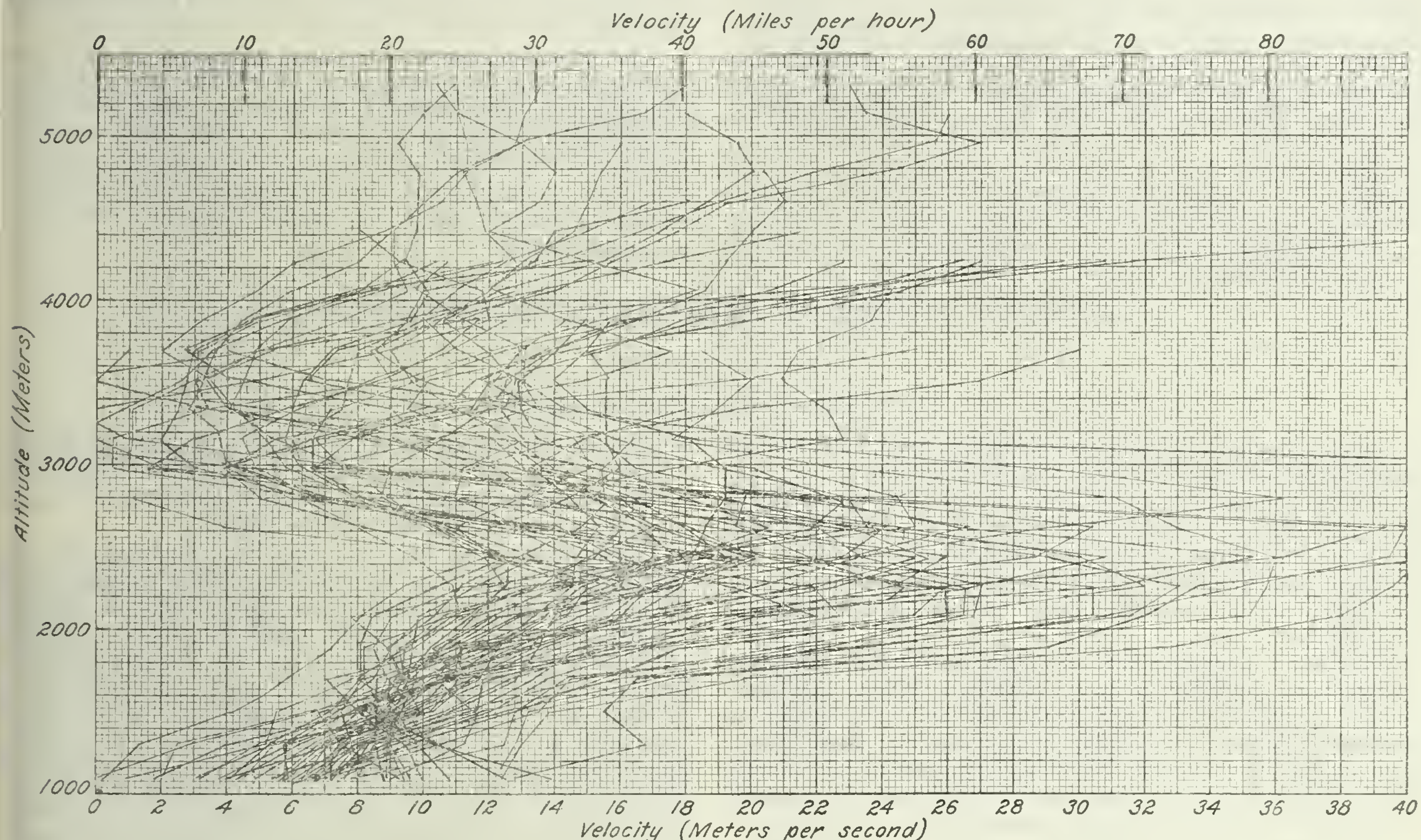


Figure 3.—Extreme velocities of northwest winds up to 6,000 meters above Lebec, Calif., from November, 1930, to March, 1931

ach 0.05 inch of pressure to bring out the gradients. 'he map is of an unusual storm in which northeasterly ales prevailed over Washington, Idaho, northern Nevada, nd northern California on the afternoon of April 22, 931.[3] The barometer reading reduced to sea level at lue Canyon on the west or leeward side of the Sierra evada, was 29.17 inches at 2 p. m., while the reading at acramento was 29.36, and at Reno 29.48. When the lue Canyon barometer was falling steadily, the writer nt five messages over the airways teletype system to erify the accuracy of readings. Later he personally lked to the observer and examined the original record hourly observations. All readings made during the ay are considered accurate. No instrumental error, or ror in method of reduction to sea level, is apparent, as e reduced readings, for Blue Canyon a day or more ter returned slowly to their normal values, as shown by e mercurial barometer readings for Sacramento and eno, but only after the northeasterly upper air winds ased. The area of low barometer on the leeward side the mountain barrier was caused, no doubt, by the fect of northeast gales on crossing the Sierra Nevada. Dust and sandstorms from northeasterly gales were ry bad in Washington, Oregon, and northern California that afternoon, and the following day the S. S. *Maui* ported a heavy dust storm at sea approximately 500 iles west-southwest of the Golden Gate. This rather traneous statement will assist the reader in identifying e day on which this meteorological situation prevailed.

cf. Cameron, Donald C., great dust storm in Washington and Oregon April 21-24, l. This Review 59:195-97.

resultant graphs were selected from as nearly simultaneous observations as possible. It will be noted that the resultant velocity at 11,000 feet above sea level at Lebec

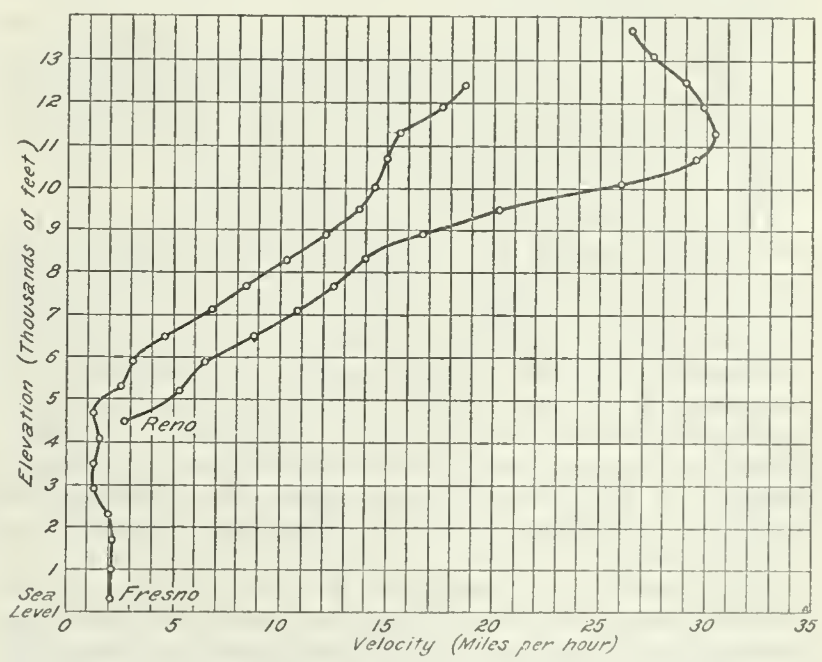


Figure 4.—Resultant velocities of west and southwest winds over Reno, Nev., and Fresno, Calif., during the period November, 1930, to April, 1930, inclusive. Resultants computed from 45 runs at Reno and 36 at Fresno most of which were made approximately simultaneously and the data are nearly complete to high levels

s approximately one-third less than at the same elevation over Fresno and Los Angeles. In several individual cases when the winds over Lebec were northwesterly, a light

southeasterly wind has been noted at 11,000 feet above sea level with northwesterly gales below and aloft. An explanation of this phenomenon is offered herewith. The extreme velocity at 8,000 feet represents an increase in kinetic energy with a corresponding decrease in pressure energy according to the Law of Conservation of Energy.[4] The extreme velocity or kinetic energy is reduced after passing over the mountain range with a corresponding increase in pressure energy which acts similarly to a pressure head in a body of water when a rapidly moving stream enters it. There is a return flow on each side of the fast-moving stream, but in the case of the air moving rapidly over a mountain barrier the return flow is manifest only above and below the rapidly moving air stream. The return flow near the surface on the leeward side of a mountain barrier has often been noted. The return flow aloft is superimposed upon the velocity of the air mass moving over the mountain barrier which corresponds to a marked decrease in velocity. In the case of Lebec, the phenomenon has its maximum effect at 11,000 feet above sea level.

The phenomenon of increased pressure on the windward side and decreased pressure on the leeward side of mountain barriers should be kept in mind during the preparation of weather charts. It will often solve the question of apparent discrepancies in barometer readings and it is an important clue to direction and velocity of upper air winds when the latter data are missing on synoptic charts.

[4] For the mathematics of this phenomenon see page 206, second edition, Physics of the Air, by W. J. Humphreys.

DESERT WINDS IN SOUTHERN CALIFORNIA

By FLOYD D. YOUNG

[Weather Bureau office, Pomona, Calif., July 20, 1931]

The southern California coastal plain, one of the richest agricultural sections in the world, depends to a great extent on the mountain barriers on the immediate north and east for its comparative freedom from continental climatic influences. The mountains are effective for the most part in shutting out the desert climatic extremes, but there are times when they fail to afford complete protection.

Whenever a strong area of high barometric pressure moves in or develops over the Plateau region, the barometric gradient calls for northeast or east winds in southern California. Winds from either of these directions bring air from the elevated land areas of Nevada and nothern Arizona. The descent of this air to sea level along the southern California coast causes a warming by compression in the neighborhood of 27° F. When we consider that these desert air masses usually are relatively dry before this mechanical warming takes place, it is easy to account for the extremely low humidities sometimes registered during the progress of a desert wind in southern California.

Desert winds may occur in southern California almost any month in the year, but those which come during the summer months are usually light, and of minor importance from the standpoint of damage to crops. They do, however, cause exceptionally high temperatures and low humidity, with consequent acute fire hazard.

The most destructive desert winds occur during the fall and winter months, when temperatures are likely to be close to zero in Nevada. During the progress of these winter winds, temperatures usually are not unseasonably high in southern California, but the relative humidity is sometimes extremely low. Readings of the sling psychrometer at Pomona, made with the utmost care, have indicated relative humidities of 3 per cent. Psychrometer readings at such low humidities are, of course, subject to error, but it is probable that the relative humidity falls about as low in this region as anywhere in the world.

The air moving outward from the Plateau high-pressure area is blocked on the south by the San Gabriel and San Bernardino Mountains. Wherever there is a break in these southern chains, such as Cajon Pass, the desert air streams through it and out onto the Great Valley of southern California. If the pressure difference between Neavada and southern California is only moderate (0.16 to 0.40 inch) the desert winds usually are confined to rather narrow belts extending from the mouths of the passes to the ocean by the lowest and least obstructed routes. The air stream which issues from Cajon Pass under these circumstances probably is of greater interest and importance than any of the others.

Cajon Pass lies between the San Gabriel and San Bernardino Mountain ranges, extending roughly north and south, turning toward the southeast near its southern extremity. It is a V-shaped notch about 17 miles long and quite narrow, extending from the Mojave Desert on the north to the Great Valley of southern California on the south. The slope from the summit of the pass northeastward to the Mojave Desert is gradual, the summit being only slightly higher than the general level of the desert. The fall from the summit toward the south is more abrupt, averaging about 115 feet to the mile. The approach to the pass from the desert side is shaped like a great horizontal "V," with the sides formed by the mountains, which converge at the entrance.

Desert winds are seldom felt on the floor of the pass, but appear to remain at some elevation above the ground. Looking down from the San Bernardino Mountains during the progress of a moderate wind, the first clouds of dust appear about a half mile south of the southern gate.

These air streams from Cajon Pass usually maintain their identity in a remarkable manner. They move out over the valley floor (almost level to the eye, but actually sloping towards the south and west), swing toward the southwest, and either follow the canyon of the Santa Ana River through the Santa Ana Mountains or move directly over the low mountains south of the canyon and then follow a well-defined path over the almost level plains of Orange County and reach the ocean in the vicinity of Newport. On going eastward in the open country some 7 miles south of Cajon Pass, with light to gentle variable winds, one often passes abruptly into an air stream moving from the north-northeast at a velocity of 30 to 35 miles per hour. The easterly limits of the stream usually are just as well marked, and one passes from a near gale into a region of relative calm within the space of half a mile. The width of the air stream under these conditions probably will average about 5 miles. The same air current often is encountered in the perfectly open plains 15 miles or so to the southwestward with its velocity and width substantially unchanged, and relatively calm air on either side. The stream may shift its position slightly from time to time, but appears to change but little in width or velocity. Sometimes it

spreads out somewhat after passing the Santa Ana Mountains, but usually it follows a well-defined path to the ocean. It often comes over the south foothills at the western entrance to the Santa Ana Canyon, appearing in such cases to come down the hillsides in strong gusts directly along the ground.

WINDS CAUSED BY STEEPER PRESSURE GRADIENTS

The winds which have been described above are the result of moderate pressure gradients over Nevada and southern California. When the pressure difference is greater, from 0.45 to 0.70 inch, and especially when a

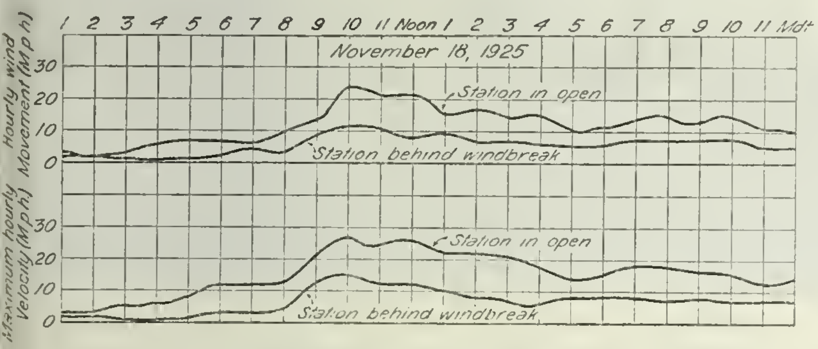


Figure 1.—Wind velocities 165 feet behind windbreak and at check station on November 18, 1925. (Four-cup anemometer)

ow-pressure area is present over Lower California, the desert winds sometimes come directly over the mountain ranges. If the gradient winds are north, the sections directly south of the San Gabriel Mountains, which extend east and west, usually are not affected, but the wind is likely to appear at the surface about 10 miles south of the mountains. Under such conditions slow eddy currents carry heavy dust into the districts near the mountains, which make it appear locally that a west wind of 6 miles per hour or less is causing a dust which blots out the sun and limits visibility to about 500 feet.

If the gradient is northeast, strong desert winds often occur in sections almost immediately south of the range. Unusually low temperatures over the Plateau region

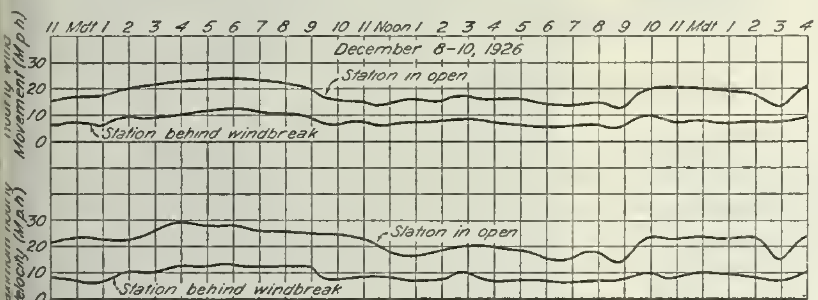


Figure 2.—Wind velocities 310 feet behind windbreak and at check station on December 8–10, 1926. (Four-cup anemometer)

commonly increase the severity of desert winds in southern California. When temperatures are relatively high over the Plateau, the winds blowing over the mountains normally remain at higher levels and do not reach the ground.

While these winds still cause heavy damage to citrus groves every few years, there is no doubt that the same pressure gradients produce surface winds of considerably less severity now than they did in the days when southern California was given over almost entirely to grazing. Windbreaks, orchard and shade trees, and buildings have moderated the fury of the gales which occurred in earlier times. Pioneer citrus growers tell of the terrific force of the desert winds of 50 years ago, of the unroofing of houses and barns, of crawling on hands and knees from house to barn to water the stock, and of the trunks of young trees almost severed by the cutting action of flying gravel and sand.

ELECTRICAL PHENOMENA

The extreme dryness of a desert wind causes charges of frictional electricity to build up on objects insulated from the ground. Heavy charges develop on the body varnish of automobiles, and when the driver reaches to

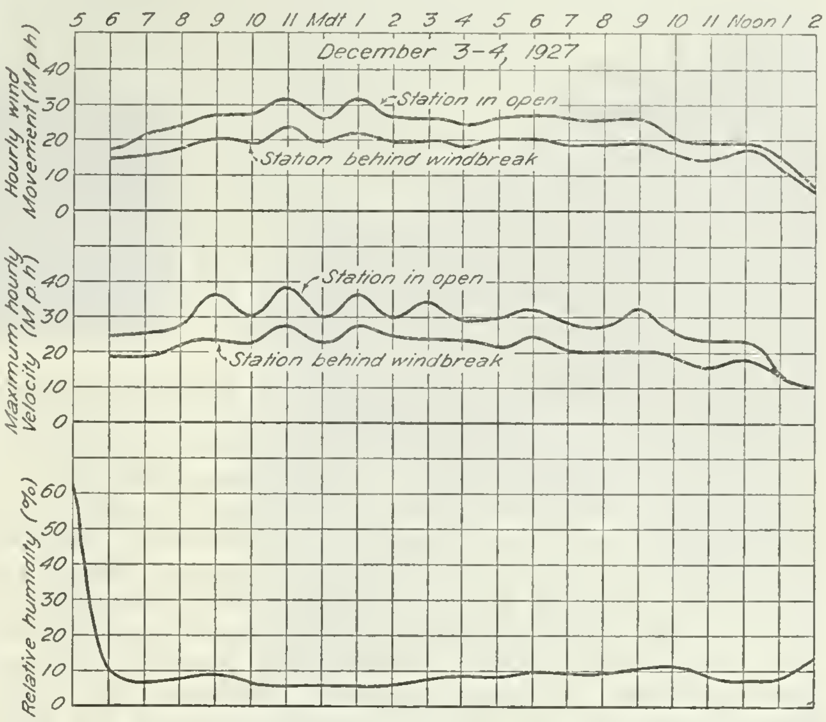


Figure 3.—Wind velocities 500 feet behind windbreak and at check station, and hourly relative humidity on December 3–4, 1927. (Four-cup anemometer)

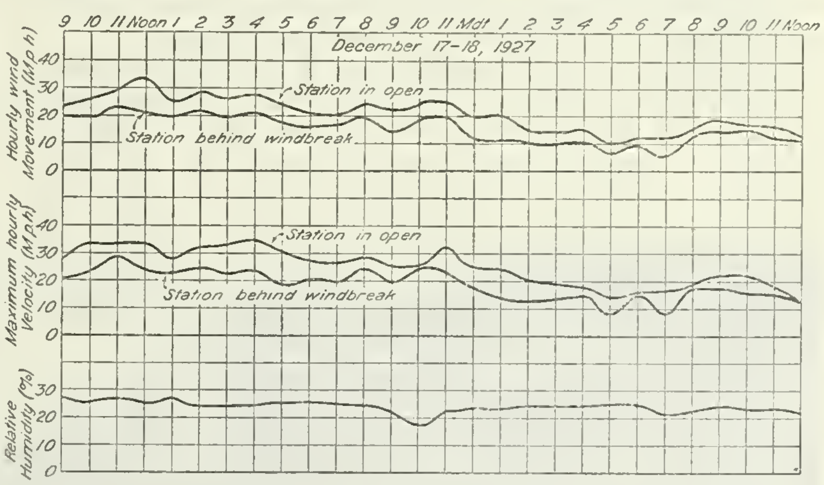


Figure 4.—Wind velocities 500 feet behind windbreak and at check station, and hourly relative humidity on December 17–18, 1927. (Four-cup anemometer)

open the door there often is an audible snap and an unpleasant sensation in the hand and arm as the discharge takes place. Reports have been made of the flashing luminosity of large pieces of bounding gravel carried by the wind at night, whenever they touched the ground. These electrical manifestations which are an accompaniment of desert winds with extremely low humidity, are erroneously believed by a large proportion of southern California residents to be the principal cause of damage to vegetation. In many sections the winds are known almost exclusively as "electrical storms."

DAMAGE TO CROPS

Damage to crops, especially citrus fruits, due to desert winds, is sometimes enormous. Citrus damage is of two kinds, the mechanical injury to the trees and fruits owing to the high velocity of the wind, and the desiccating effects of the extremely dry air on the foliage. When the wind velocity is high, 30 to 40 miles per hour, much fruit is blown to the ground and a great deal of that left on the trees is badly scarred through limb rubbing. Two desert winds which occurred in Orange County, Calif., during December, 1927, caused an estimated loss of 1,500 carloads of oranges through blowing the fruit from the trees. The manager of the cooperative marketing association in one district estimated that 35 per cent of the entire orange crop on the trees in his district was blown to the ground. In the most exposed portions of some orange groves, as many as 500 oranges were counted under individual trees after the wind. Fruit scratched or bruised through contact with limbs during a storm is much more subject to decay than sound fruit. If a period of rain or nights with heavy fog follows a strong desert wind within a few days, the injured fruits often decay on the trees.

Foliage injury, or "wind burn," as it is called locally, is due entirely to excessive dehydration of the leaves and small twigs in the extremely dry atmosphere. It is confined almost entirely to orange trees. Lemon and grapefruit trees seldom are damaged seriously. Partial defoliation of lemon trees sometimes results from desert winds, but it is due principally to the actual whipping off of the leaves by the wind rather than desiccation. Probably few fruits are grown under climatic conditions more unlike their natural environment than the citrus. The cultivated varieties of citrus originated in hot, humid climates, with heavy rainfall, and grew for the most part under partial shade.

It is not surprising, therefore, that they have difficulty in adjusting themselves to the extremely low humidity and relatively high velocity of the desert winds.

In December, 1927, orange trees in an area of about 35 square miles in Orange County, Calif., suffered about 20 per cent defoliation in two desert winds. (See figs. 3 and 4.) Most of this damage occurred in a period of less than 24 hours during the first storm. The more exposed orange groves suffered more than 50 per cent defoliation, and some individual trees were almost completely denuded of leaves. The shock to the trees materially reduced the size of the crop during the following season.

In the fall of 1924 defoliation due to desert winds in the same district was even greater than in 1927. Trees left in a weakened condition from loss of foliage were damaged much more severely by low temperatures in late December of the same year than those which had suffered no foliage injury.

Investigations made by the University of California and others have shown that defoliation by desert winds can be reduced through maintaining the trees in a thrifty condition and developing vigorous root systems, and by having adequate supply of moisture available to the trees immediately prior to the onset of the wind.

EFFECTIVENESS OF WIND BREAKS

Following the damaging desert winds in the fall of 1924, a study of the effect of windbreaks on the wind velocity and relative humidity was undertaken by the fruit-frost service of the Weather Bureau, in cooperation with the Villa Park Orchards Association and the Orange County Fruit Exchange. Records of wind velocity, relative humidity, and temperature were obtained at two stations in a citrus district subject to desert winds, one in an area without windbreaks and the other at varying distances behind a windbreak about a mile to the westward in the same general location. The windbreak was 1,280 feet long and extended north and south. Approximately one-half its length was made up of eucalyptus (blue gum) trees, about 95 feet high, and one-half Montrey cypress, about 70 feet high. (See fig. 5.) The windbreak trees were 30 years old. The orange trees, set 24 feet apart on the square, were 28 years old. Anemometers at both stations were placed 18 feet above the ground, or about two feet above the tops of the trees. Thermometers and hydrographs were exposed in fruit-region instrument shelters in the orange groves, 4.5 feet above the ground. The wind-break station was set 165 feet to the leeward of the windbreak the first season, 310 feet the second season, and 500 feet the third season. Wind velocities in the open (check station) and behind the windbreak during the progress of desert winds, are shown in the table below.

Smoothed records of hourly wind velocity during the progress of desert winds, at distances of 165 feet and 310 feet, respectively, behind the windbreak, and at the check station, are shown in Figures 1 and 2.

	Average hourly wind velocity [1]	Average hourly maximum velocity (5 minutes) [1]	Maximum velocity period of wind [1]
Nov. 18, 1925:			
Check station	12.0	15.0	27.0
165 feet behind windbreak	5.5	6.5	15.0
Decrease due to windbreak per cent	54	57	44
Dec. 8-10, 1926:			
Check station	18.0	22.0	29.0
310 feet behind windbreak	8.0	9.0	13.0
Decrease due to windbreak per cent	56	59	55
Dec. 3-4, 1927:			
Check station	23.1	27.6	38.0
500 feet behind windbreak	17.3	20.3	27.0
Decrease due to windbreak per cent	25	26	29
Dec. 17-18, 1927:			
Check station	20.4	25.7	34.0
500 feet behind windbreak	14.8	18.1	28.0
Decrease due to windbreak per cent	27	30	18

[1] Four-cup anemometers used.

The records indicate that the effectiveness of the windbreak is as great at 310 feet as at 165 feet, and that its effectiveness decreases by approximately 50 per cent at a distance of 500 feet. The openings between the trunks of the wind-break trees were large enough near the ground to permit considerable air movement through them, while higher up the heavy foliage of adjoining trees was interlaced, leaving few open spaces. It is believed that the wind entering the orchard near the ground increased the velocities shown at the 165-foot station and accounted for the lack of difference between the velocities at 165 feet and 310 feet. This breeze coming in between the tree trunks very close to the ground undoubtedly was spread and dissipated to a large extent by the resistance of the orange trees before it had traveled far into the orchard.

The two winds which occurred in December, 1927, noted in the table, caused considerably more damage to citrus trees and fruits than any others experienced during the time the wind-break study was carried on. Smoothed records of hourly wind movement and maximum hourly velocity at the check station and the station 500 feet behind the windbreak are shown in Figures 3

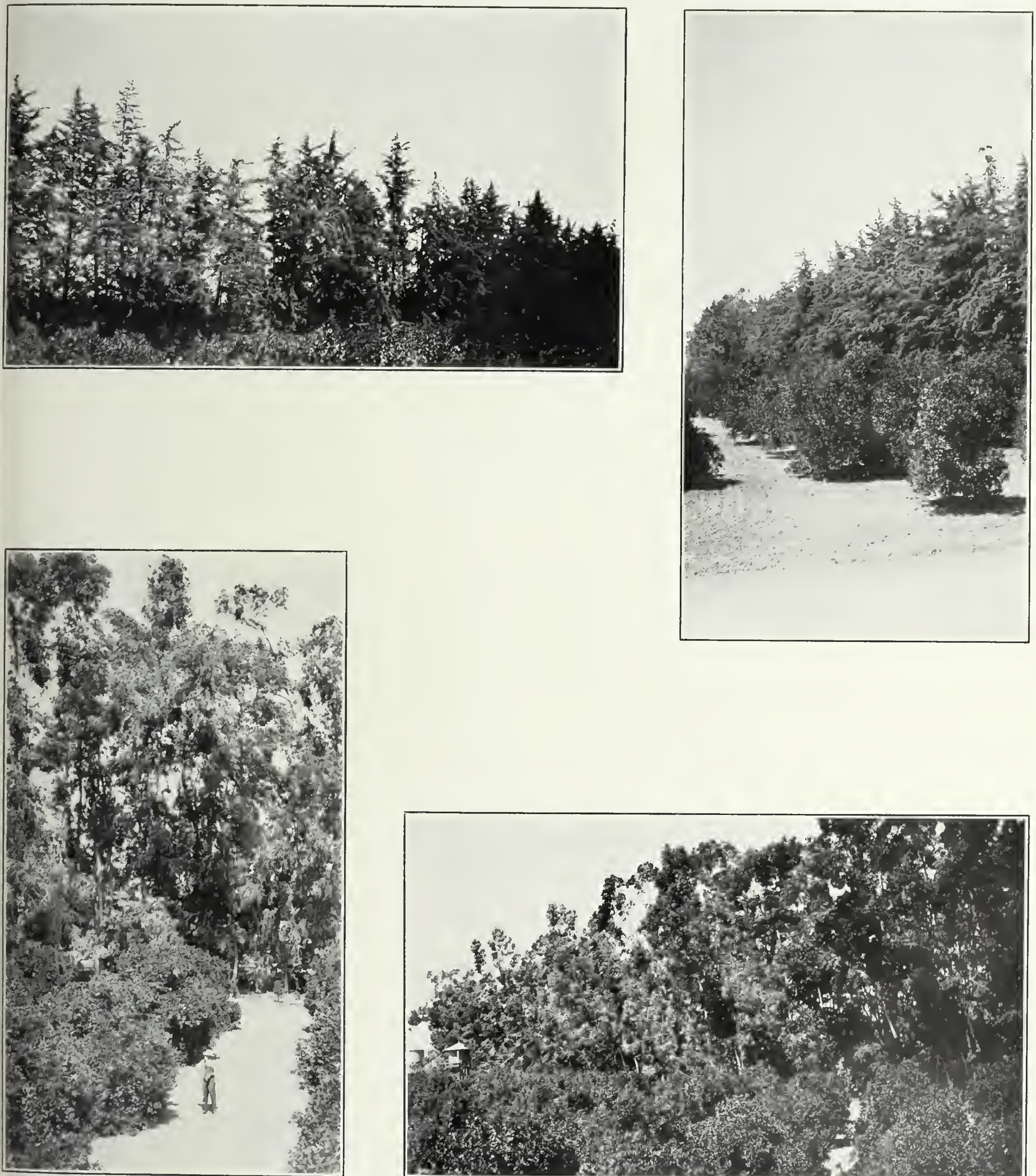


FIGURE 5.—Views of Eucalyptus and Cypress windbreak used in experiment

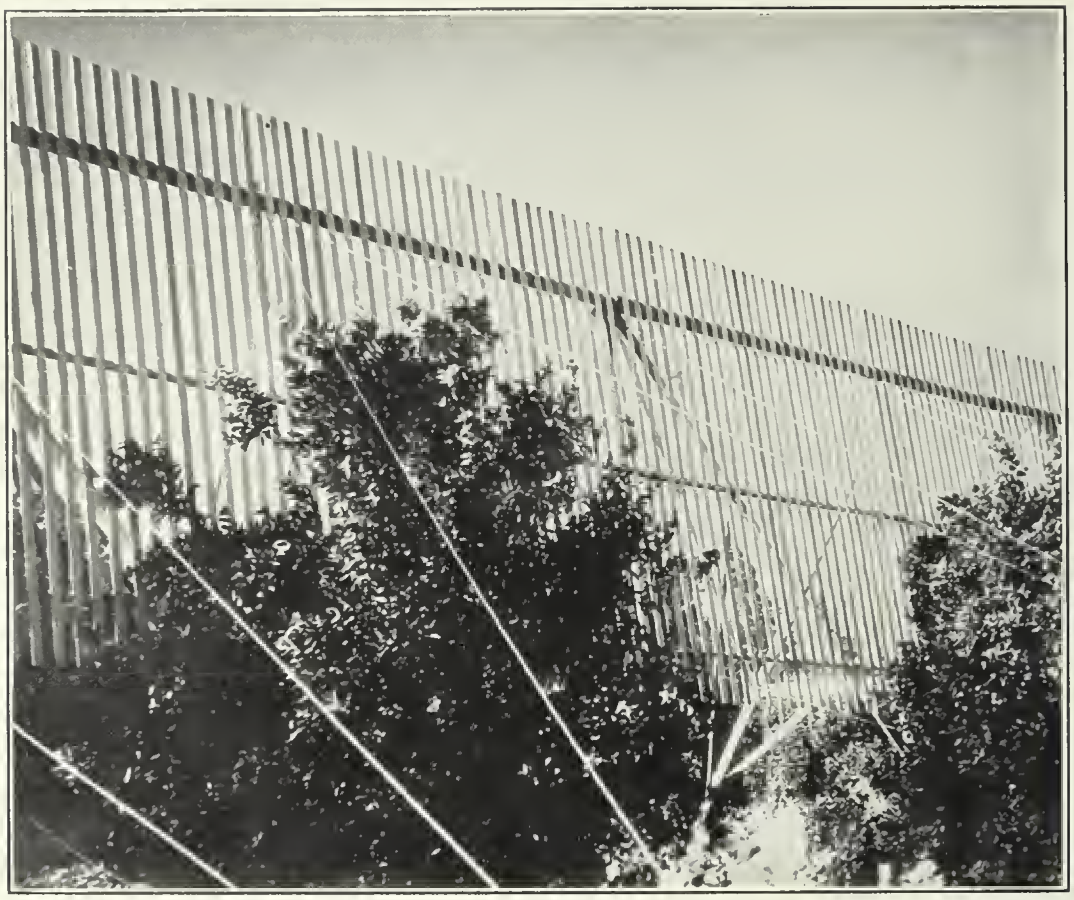


FIGURE 6.—Views of artificial windbreak 28 feet high in orange grove near El Modena, Calif. Many different types of artificial windbreaks have been developed, but none has been very successful in protecting mature citrus trees. Photos by H. A. Rathbone

ınd 4. Smoothed records of hourly relative humidity, aken from a carefully checked and regulated hair hygro-;raph, are included.

The records obtained during these two wind storms as vell as the records of many lighter and less destructive lesert winds, indicate quite definitely that "wind burn-ng" of citrus trees occurs only when the relative humidity s unusually low. Heavy winds without excessively low elative humidity have caused no burning whatever, vhile relatively light winds with low humidity have ever failed to cause some damage to foliage. While the ividing point on the relative humidity scale between urning and no burning varies slightly with different vind velocities and different conditions of the trees, all he records obtained in this study indicate that foliage urn is suffered only when the relative humidity falls to 0 per cent or lower. So far as could be determined, all he foliage burn which occurred during December, 1927, as caused by the first desert wind, on the 3d and 4th. 'he second wind, on the 17th and 18th, blew off many aves which had been damaged in the earlier storm, but pparently caused no new burning. The second wind lew considerably more fruit from the trees than the first ne, but this was owing to the fact that the loss of foliage uring the first wind left the fruit on the inside of the ees without protection.

A careful inspection of the two orange groves in which ie wind-break studies were carried on was made im-ıediately after the desert winds of December, 1927. At ie check station the average loss of foliage caused by wind burning" was 30 per cent over the entire orchard. ı the orchard behind the windbreak there were very ight indications of burning in the tops of the trees for a istance of 72 feet therefrom, probably caused by the ind which came through the lower part of the break. oil moisture condition, due to the proximity of the ind-break trees, also probably was a factor. From 72 et to 288 feet from the break there was no burning what-ver. From 288 feet to 500 feet the amount of burn owly increased from zero to about 2 per cent. From)0 feet to the western boundary of the orchard, 784 et from the break, the damage increased more rapidly, ıe heaviest burn appearing in the last 250 feet. In the st row the foliage burn was estimated to be approxi-ately 10 per cent.

In the orchard protected by the windbreak no fruit as blow off the trees for a distance of 288 feet. From is point to the 500-foot line fruits on the ground aver-;ed four to the tree. From 500 feet to the western order of the orchard, 784 feet from the windbreak, the ımber of fruits per tree on the ground increased rapidly. count of oranges under 10 trees in the last row showed ı average of 30 per tree.

The number of oranges per tree on the ground in the check orchard varied from 98 to 452, with an average for all parts of the grove of 163.

The relative humidity was always somewhat higher behind the windbreak during relatively light desert winds, but there was little difference between the two stations during the heaviest winds.

These studies indicate that a windbreak such as the one for the orchard in which the records were obtained, affords practically complete protection from desert winds, both as to loss of fruit and damage to foliage, up to a distance of about 500 feet, and partial protection up to at least 800 feet from the break. Data on wind damage show the necessity for an adequate system of wind-breaks throughout the sections visited most frequently by desert winds. The disastrous effects of desert winds in 1924 and 1927 resulted in the planting of many miles of new windbreaks in portions of Orange County, but lack of severe winds in recent years has resulted in many of them being removed. Large windbreak trees compete for food and moisture with citrus trees in adjoining rows, and cause some reduction in the crop of fruit. Also the planting of windbreaks throughout a large area increases the frost hazard to some extent. However, the protection from desert wind damage far outweight either of these factors in the districts most subject to wind damage.

Many different types of windbreaks have been devised in addition to the familiar lines of growing trees. Views of artificial windbreaks erected in an orange grove near El Modena, Calif., are shown in Figure 6. They are placed in every fourth tree row north and south, or about 96 feet apart, extend to a height of about 23 feet and are anchored firmly to heavy stakes driven into the ground. Their cost, when constructed with secondhand lumber, was slightly more than 75 cents per running foot.

Studies to determine the effectiveness of these wind-breaks were carried on during the winter of 1930–31. Unfortunately the wind direction at the chosen location was subject to change from north to east, or vice versa, during the progress of desert winds, so that the wind direction was sometimes parallel to the windbreaks. When the wind was in the east its velocity midway between two breaks was reduced by approximately 50 per cent, but when the wind direction changed to north, the velocity was sometimes stronger between the breaks than at the check station. The windbreak structures with-stood velocities as high as 20 miles per hour without any indication of weakness.

Acknowledgment is due Mr. Harold A. Rathbone, junior meteorologist in the Weather Bureau, for installing and caring for meteorological equipment at the two wind stations, and for keeping records of wind damage. The writer is grateful for his assistance.

;NOW COVER IN SOUTHERN CANADA AS RELATED TO TEMPERATURES IN THE NORTH ATLANTIC STATES AND THE LAKE REGION

By R. H. Weightman

[Weather Bureau, Washington, D. C., September 25, 1931]

It has been stated frequently, and apparently with ıason, that a snow cover of more than normal amount ·er central and eastern Canada in the late winter should ıtard the usual rapid rise of spring temperatures in the ıke Region and the north Atlantic States, with resultant ıw temperatures over those regions during the spring ıonths, particularly the month of April. Similarly ;ow cover greater than normal over northwestern Canada and northeastern Alaska in the late winter should be followed by low spring temperatures in the Plains States and Upper Mississippi Valley.

Amount of snowfall for the month is available at a number of stations in Canada and northeastern Alaska but the amount of snowfall during one month is not the information that will have the most direct bearing on temperatures in our northern border States in the follow-

ing month. The feature that should have the most important effect is the depth of snow at the end of the month, as for example March as affecting temperatures in April. This is true because the greater the depth of snow, the longer will the snow cover last, other conditions being equal. The snowfall might have been considerable during the month of March and yet, due to melting and evaporation all of it and some that was already on the ground at the beginning of the month might not be available at the end of the month to exercise any effect on subsequent temperatures. It is found that for stations in southern Canada, a number of which have depth of snow at the end of the month available beginning with 1916, even with a considerable fall of snow during the month of March, the depth at the end of March was less than at the end of February. For example, the depth of snow at Ottawa at the end of February, 1916, was 41.5 inches, the fall of snow during the month of March, 1916, was 23.1 inches, while at the end of March, 1916, the total depth was only 7 inches. No data for depth of snow at end of the month are available for Alaskan stations.

Our study is therefore confined to the years 1916 to 1928, a period of 13 years in all. It was decided to enter on working charts the amount of snow on the ground at the end of March for Canada and on the same base map to draw lines in the United States showing departures from normal temperatures as taken from the MONTHLY WEATHER REVIEW. It may be questioned whether the actual depth of snow would be as good an index as either departure from normal or percentage of normal. There are, however, obvious objections to one of these methods alone so that it was decided to use a combination of them, whereby the depth of snow will be indicated and, in addition, information made available to show when the snow cover was greater or less than normal. Table 1 shows depth of snow on the ground at the end of March for 30 stations, all of which, with the exception of Dawson, are in southern Canada. The location of these stations is shown on chart 1. The figures in italics are interpolated values. The average depth at the end of March appears at the foot of each column. Charts 2 to 14 show by black lines the depth of snow on the ground at the end of March in southern Canada for the 13-year period, 1916–1928, while red hatchings show areas where snow cover was greater than normal. Departures of temperatures from normal in the United States for April, as taken from the MONTHLY WEATHER REVIEW, are shown by red lines.

NORTH ATLANTIC STATES

It was decided to first compare outstanding cold and warm months in the North Atlantic States district No. 1 (see Chart No. 1), followed later with similar comparisons for the Lake region, district No. 3, and then take a few cases of the extensive cold and warm months for northern States from the eastern slope of the Rocky Mountains to New England. Districts 1, 3, 4, 5, and 7.

Let us first examine Aprils with temperatures 1° or more below normal in the North Atlantic States as represented by the means of 10 stations well distributed in New England, central and eastern Pennsylvania and eastern New York. They were 1917 (−1.5°), 1920 (−1.7°), 1926 (−3.6°), and 1928 (−1.4°). We may summarize briefly the snow cover conditions in southern Canada at the end of March for these years, as follows:

1917.—Above normal over the middle and lower St. Lawrence Valley with an area extending westward to the east of Lake Superior and to the north of Lake Huron; also, over portions of Saskatchewan, and northern Manitoba. Elsewhere, so far as observations are available, snow cover was below normal. This condition was followed by April temperatures, 1.5° below normal in the North Atlantic States.

1920.—Above normal over Manitoba, central and southern Saskatchewan, and central Alberta, but considerably below normal over eastern Canada as a whole. The April temperature departure in the North Atlantic States was −1.7°.

1926.—Above normal in the St. Lawrence Valley, southeastern Ontario, and Canadian Maritime Provinces but below normal over central and western Canada. In the North Atlantic States, April temperatures averaged 3.6° below normal.

1928.—This year was very similar as regards snow cover to that of 1926, but with a temperature deficit in April of 1.4° in the North Atlantic States.

Of the four cold Aprils, three, namely, 1917, 1926, and 1928, were preceded by a snow cover greater than normal in the St. Lawrence Valley, while the fourth case, 1920, was just the opposite, as snow cover less than normal existed in that region at the end of March. The year 1923 showed the greatest and most extensive snow cover at the end of March of any year of the series for which data are available. The region with above normal depth extended from the Canadian Maritime Provinces westward over Quebec, Ontario, central and southern Manitoba and Saskatchewan. Temperatures in the North Atlantic States were, however, only 0.4° below the normal. The next heaviest month was March, 1916, with snow cover above normal, extending over all of Ontario and northern Manitoba, being followed by April temperature departures in the North Atlantic States of only −0.2°.

The other months of March had snow cover either very close to or below the normal over the St. Lawrence Valley region, in practically all cases being followed by near or above normal April temperatures in the North Atlantic States, except in 1920, when with considerably below normal snow cover in the St. Lawrence Valley and westward over Ontario, the April temperature averaged 1.7° below normal.

We have thus far examined years in which the April temperatures in the North Atlantic States were below normal. Let us now give attention to years in which temperatures in that region were 1°, or more, above normal, as follows: 1921 (+5.6°), 1922 (+1.8°), and 1925 (+2.2°).

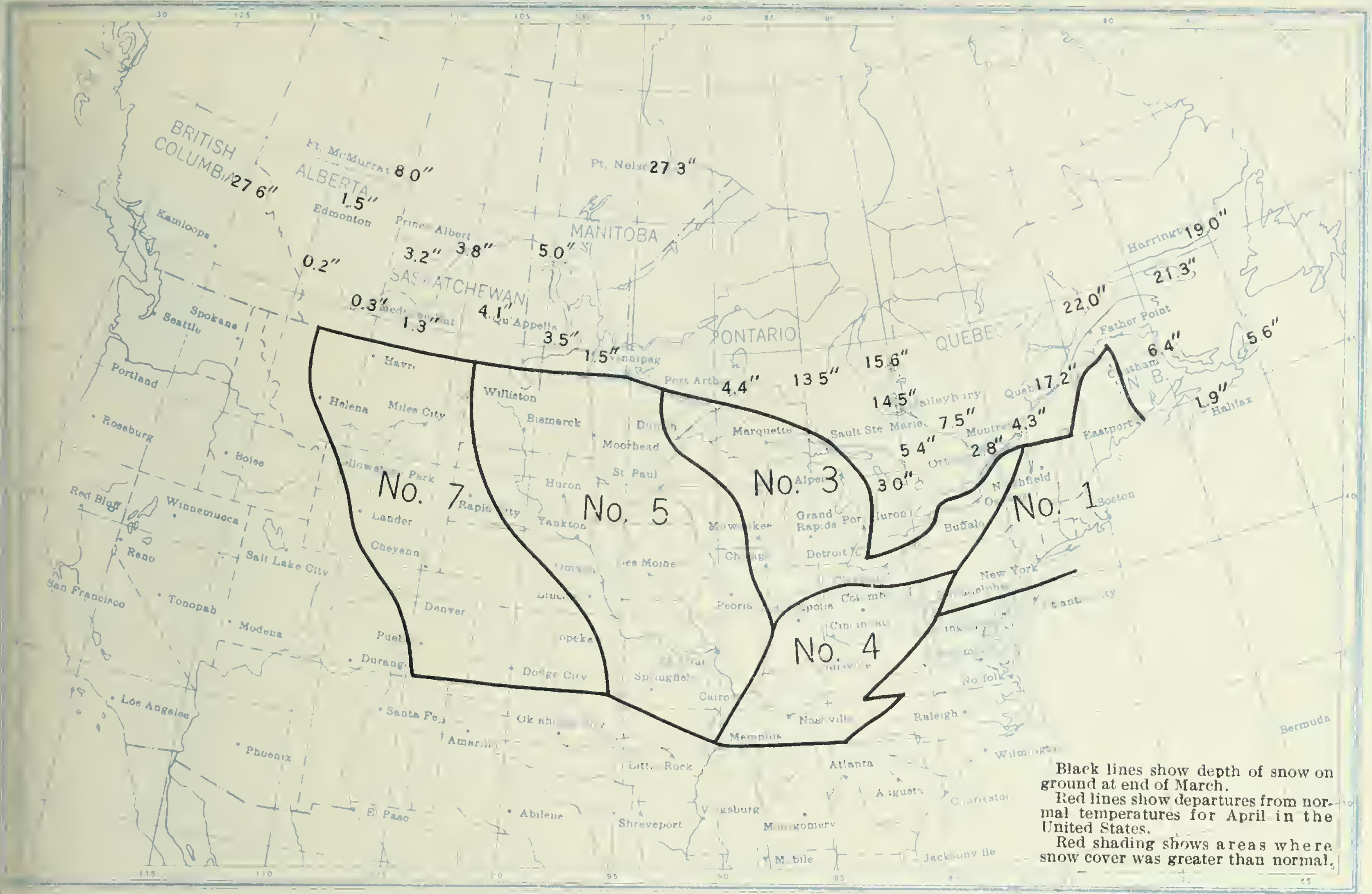
1921.—Snow cover was less than normal at the end of March over central and eastern Canada, being much below in the St. Lawrence Valley and in Ontario from Port Arthur eastward to Cochrane and Haileybury the only area of above normal cover was over northern Saskatchewan and northern Manitoba. These conditions were followed by April temperatures in the North Atlantic States, 5.6° above normal.

1922.—Snow cover was below normal in the St. Lawrence Valley, western Ontario, and southeastern Manitoba, being followed by an April temperature departure in the North Atlantic States of +1.8.

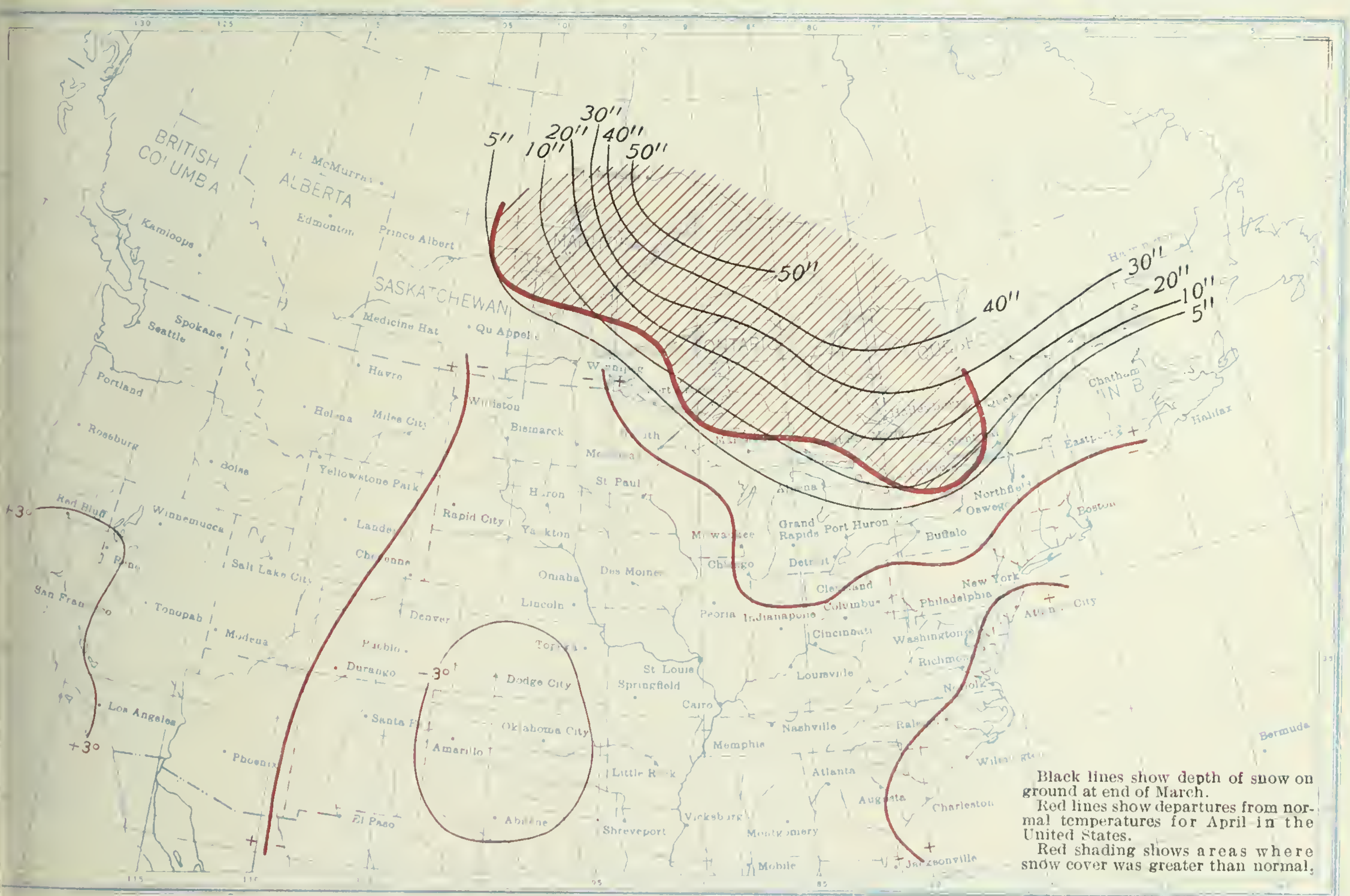
1925.—Snow cover was below normal in the St. Lawrence Valley except at Quebec, in eastern Ontario except at Cochrane, and in Saskatchewan and Manitoba, being followed in April by temperatures 2.2° above normal in the North Atlantic States.

In all three cases of warm Aprils in the North Atlantic States, snowfall was below normal in the St. Lawrence Valley.

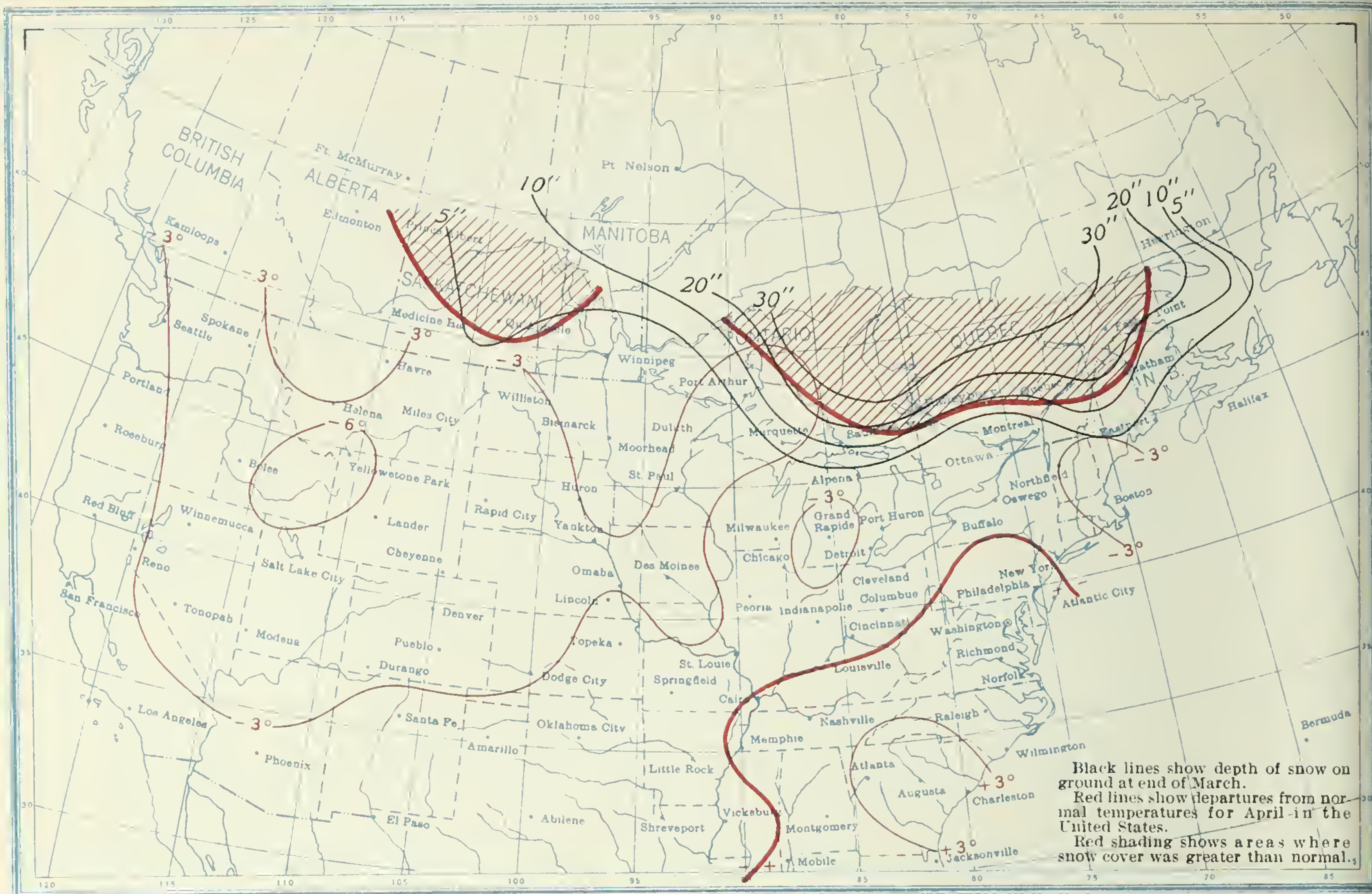
Average Snowfall at End of March



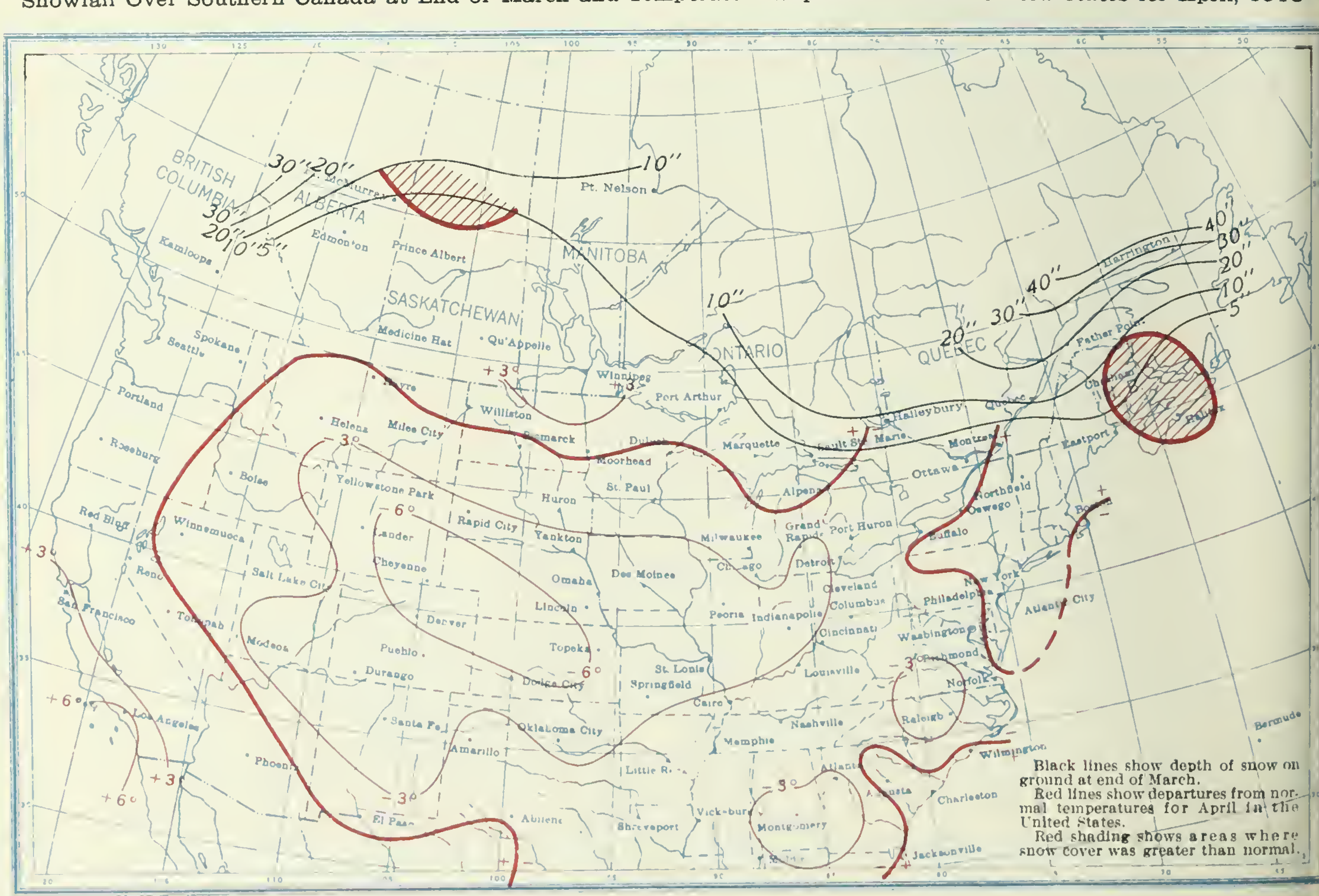
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1916



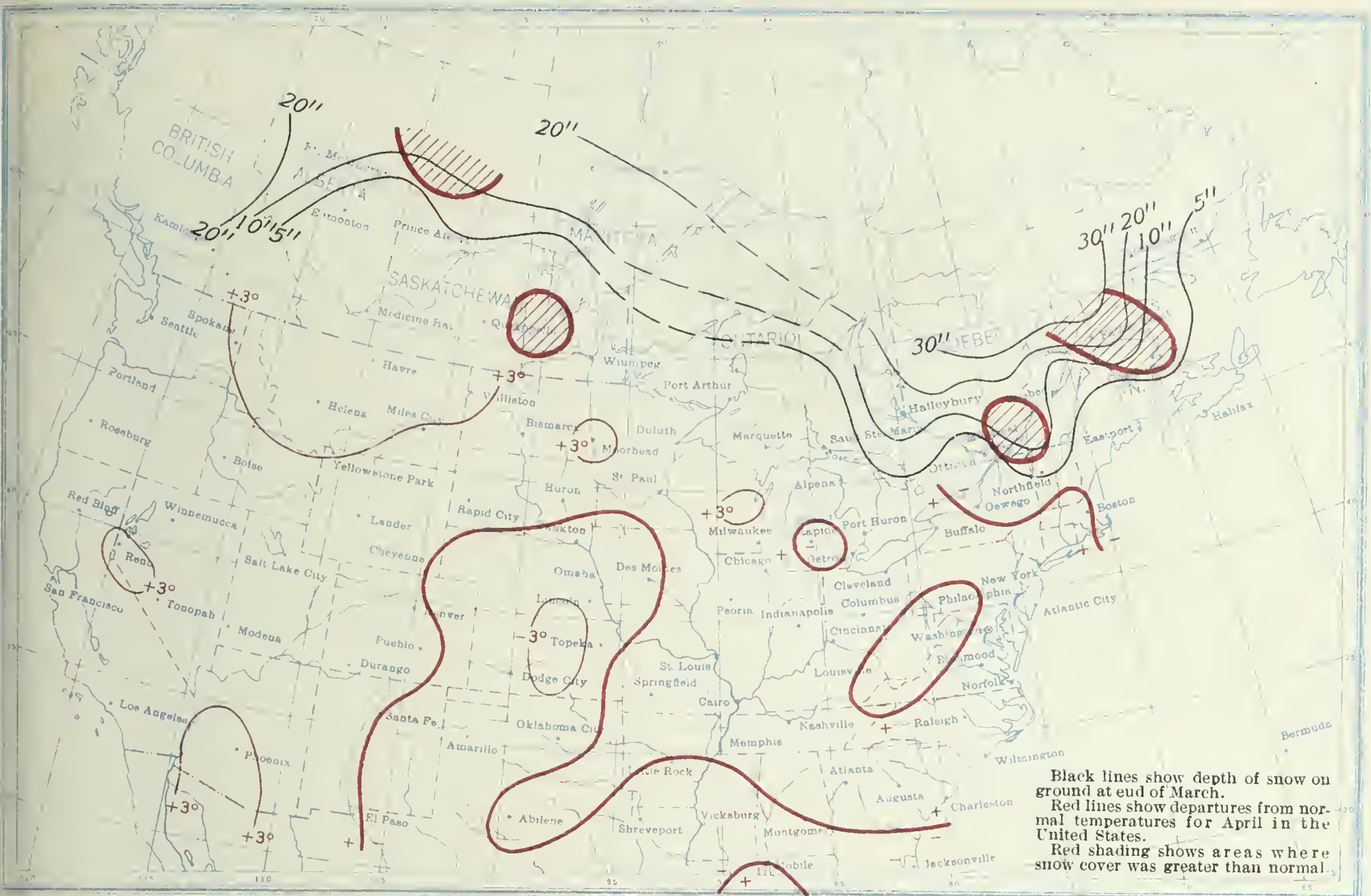
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1917



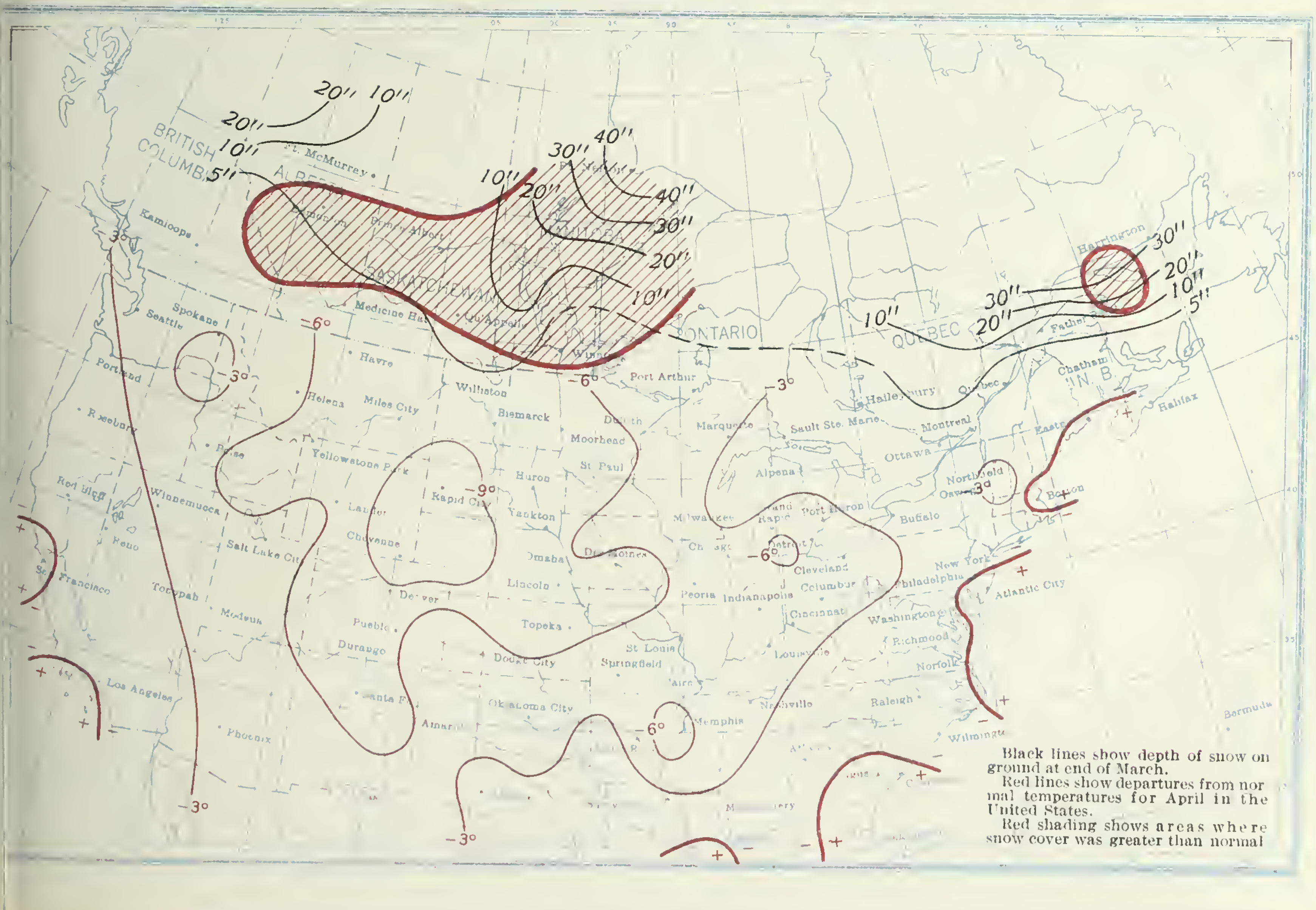
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1918



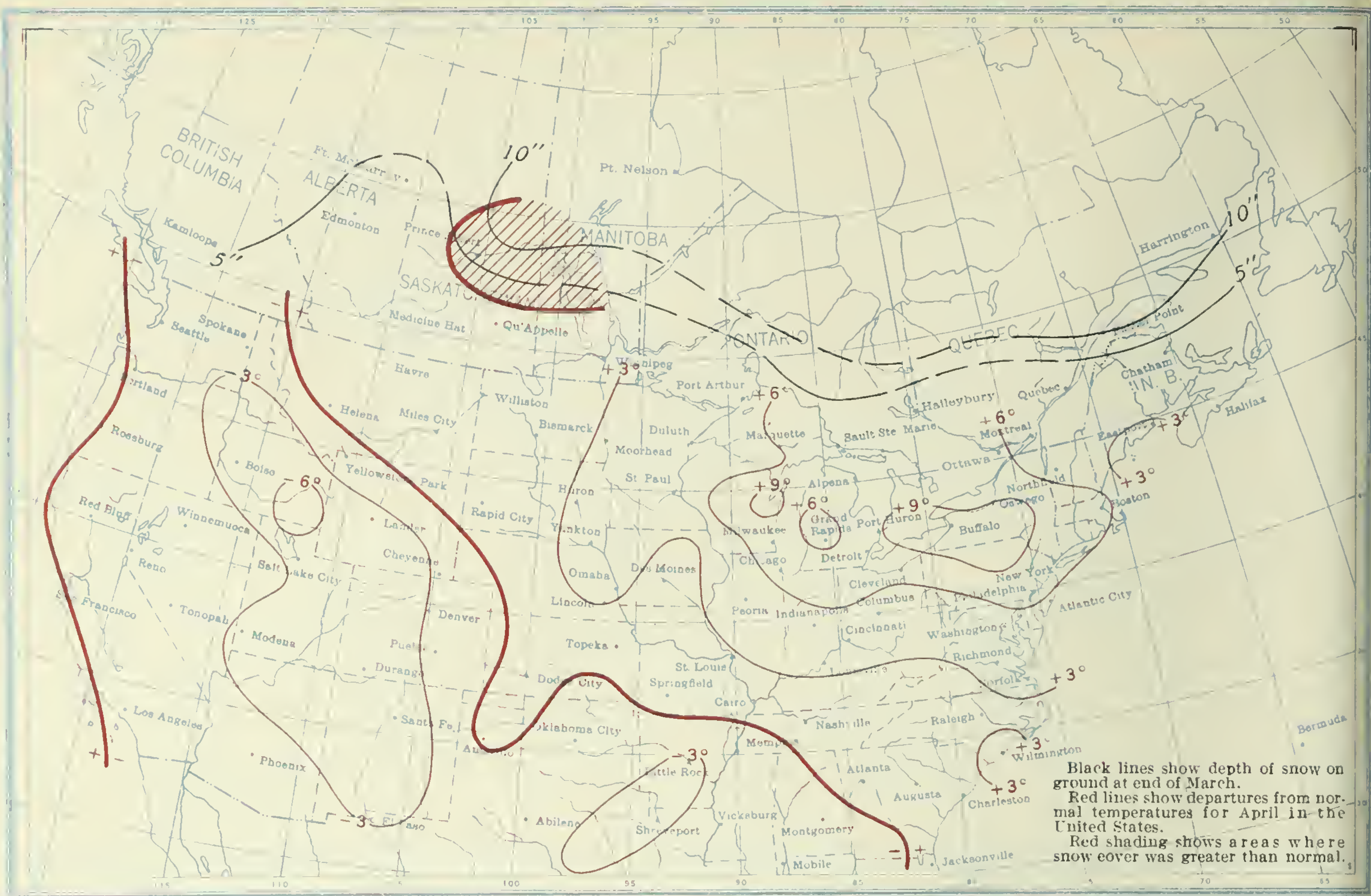
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1919



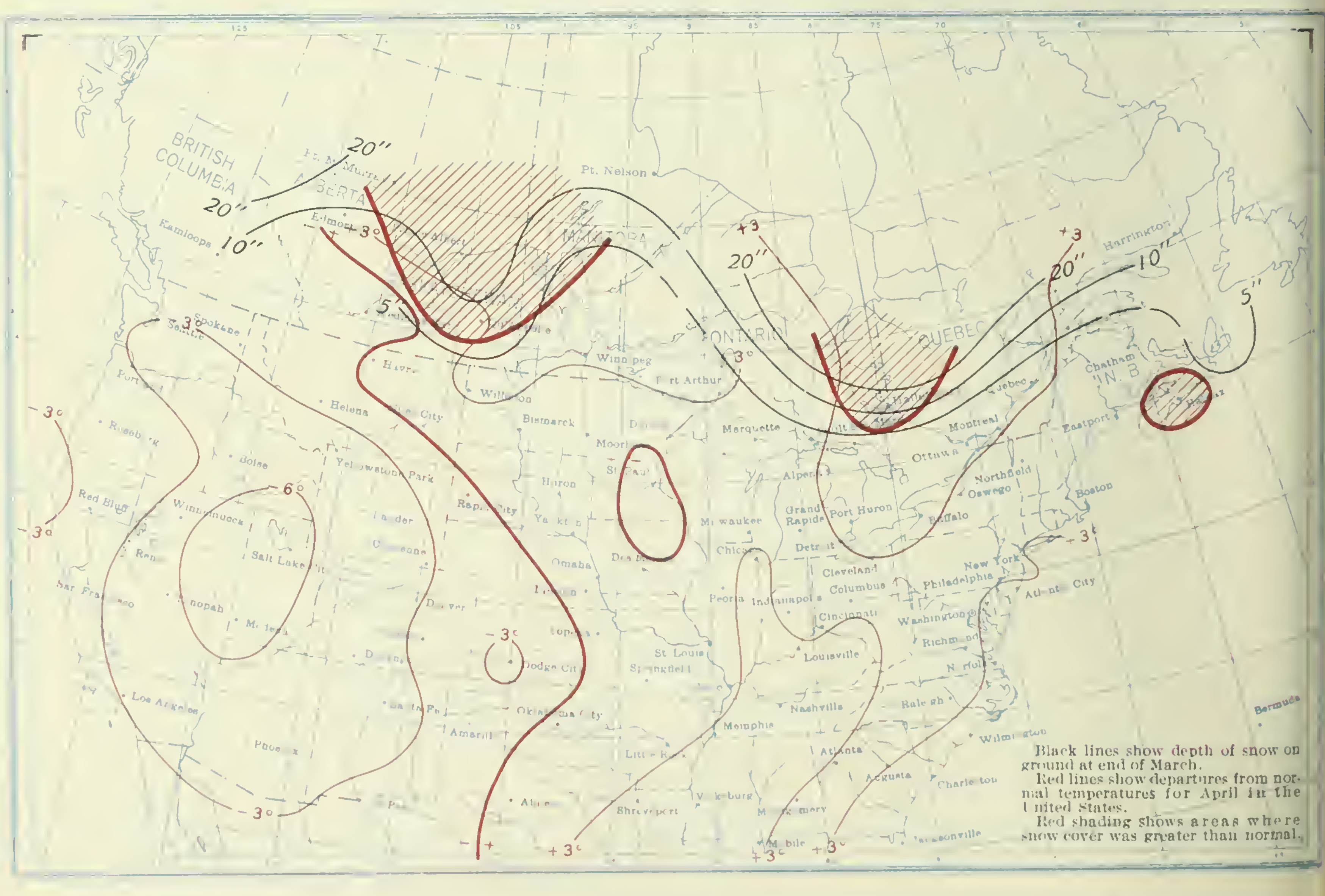
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1920



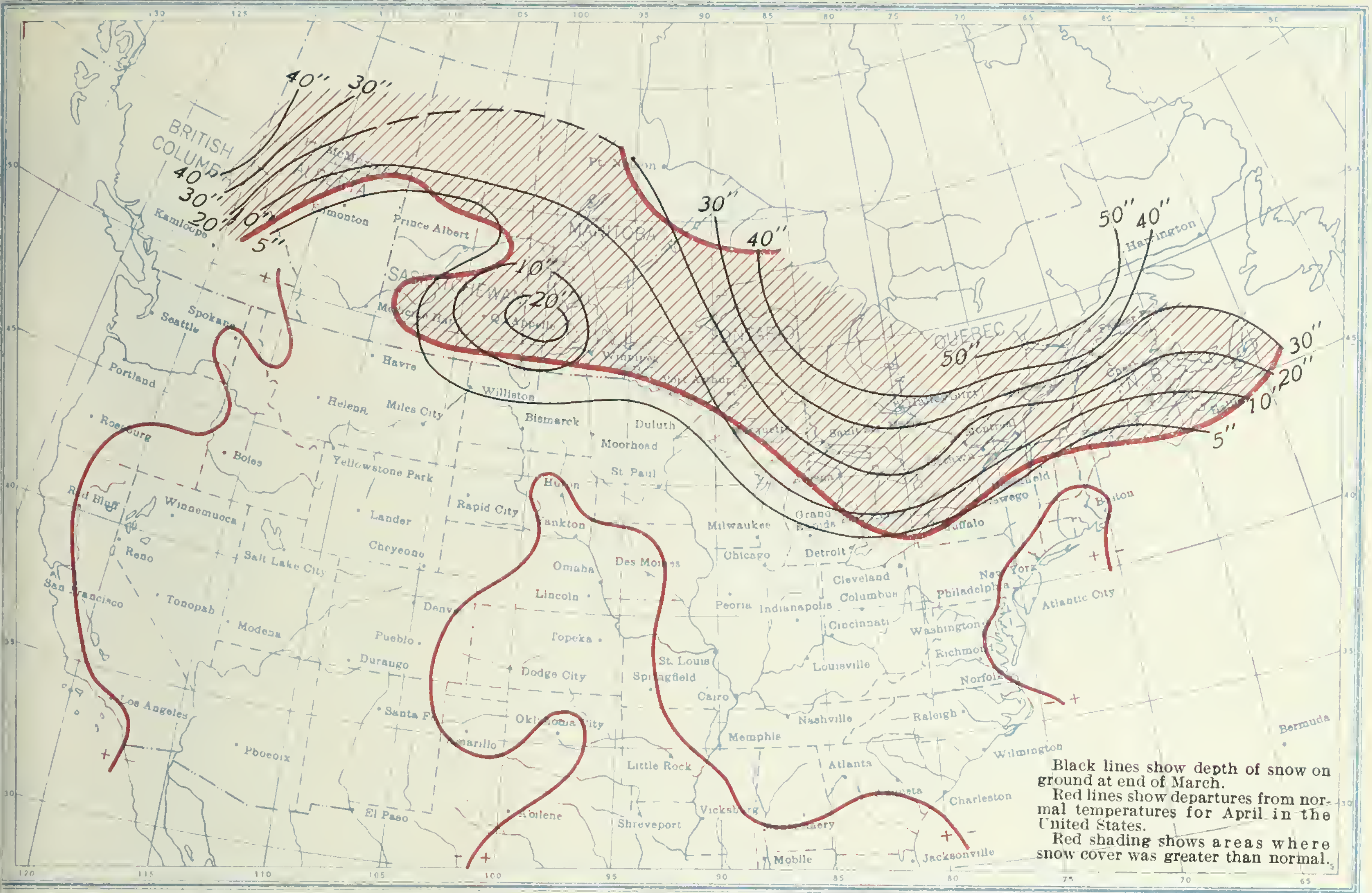
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1921



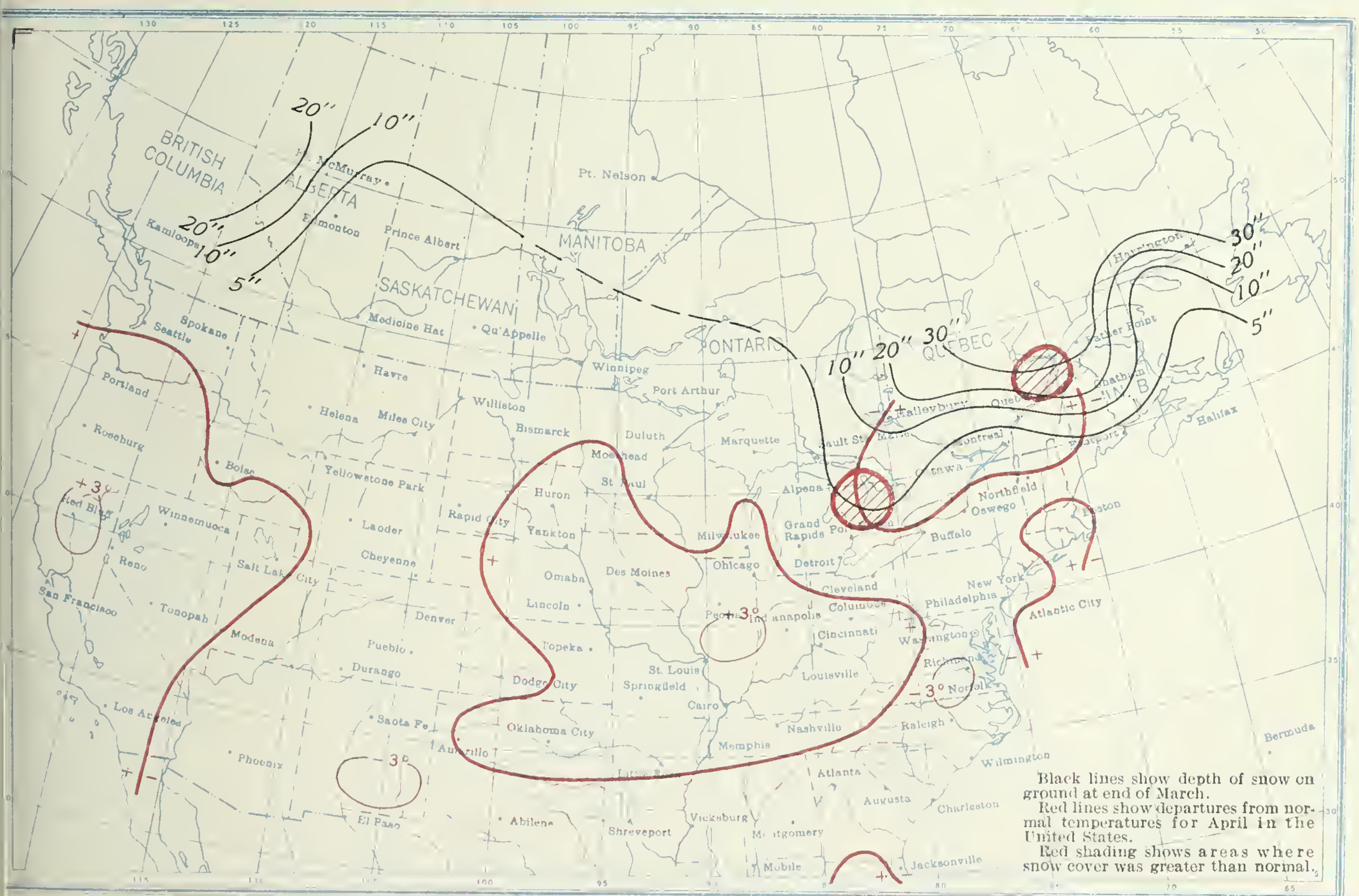
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1922



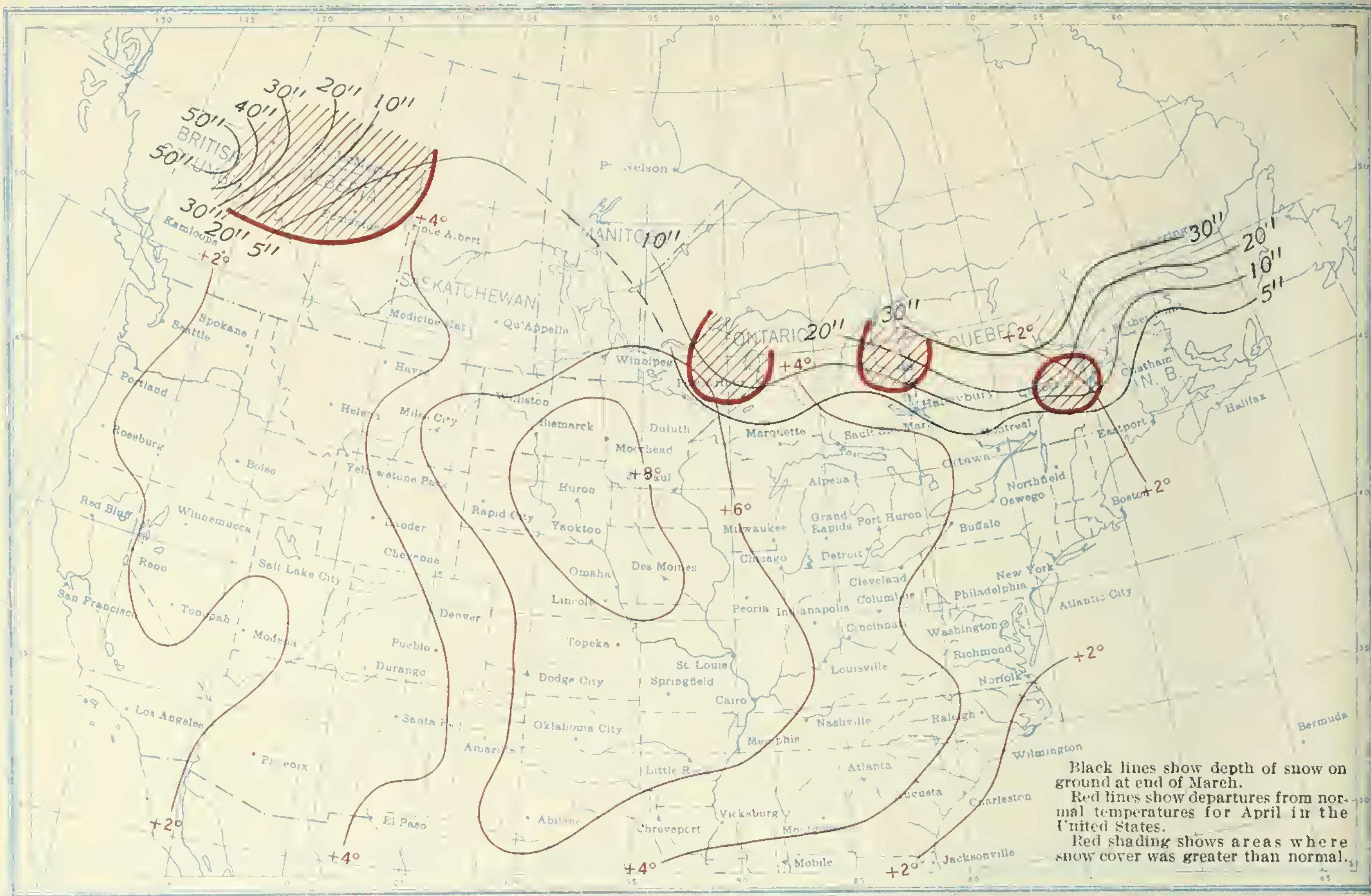
Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1923



Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1924

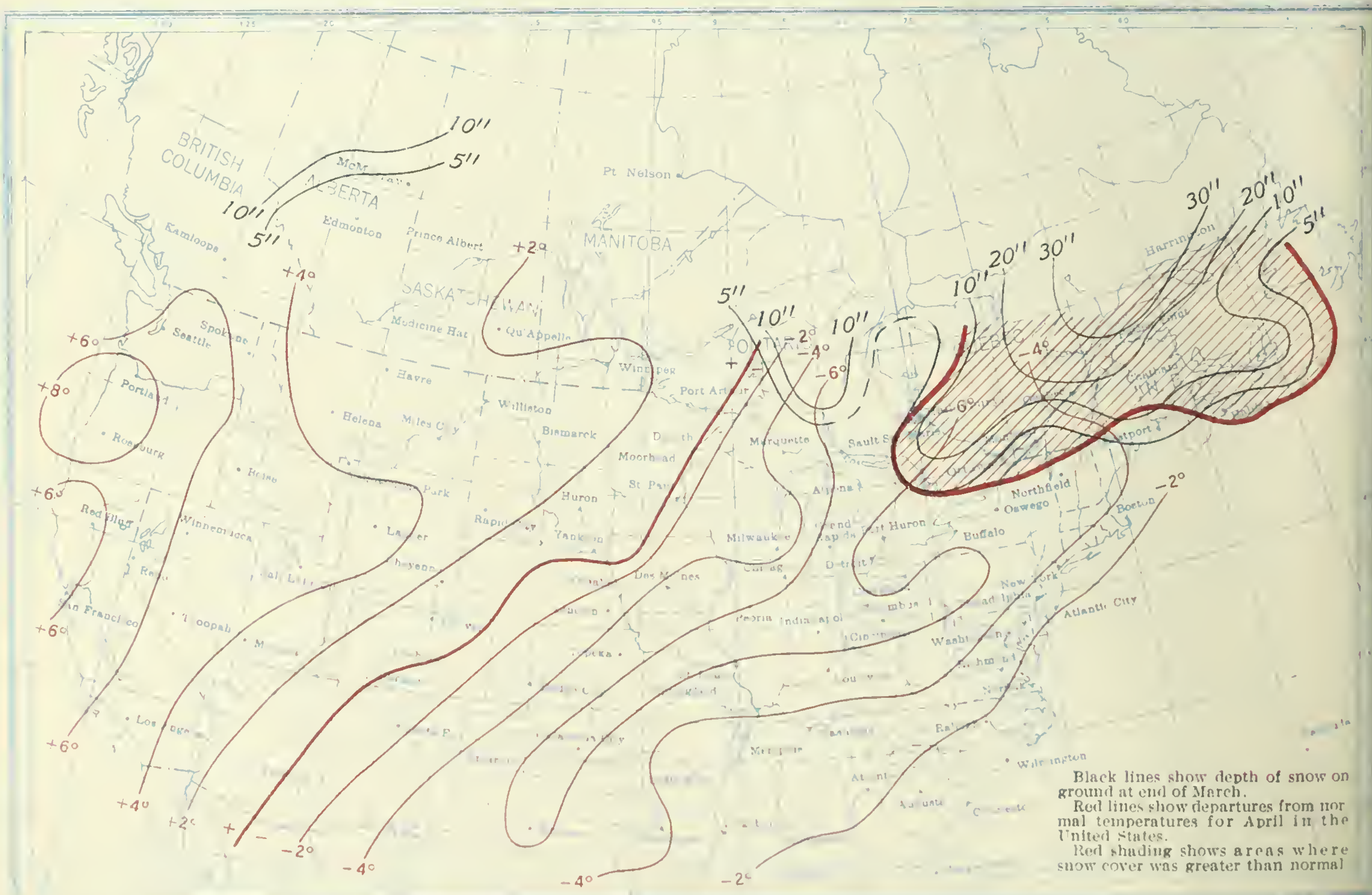


Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1925



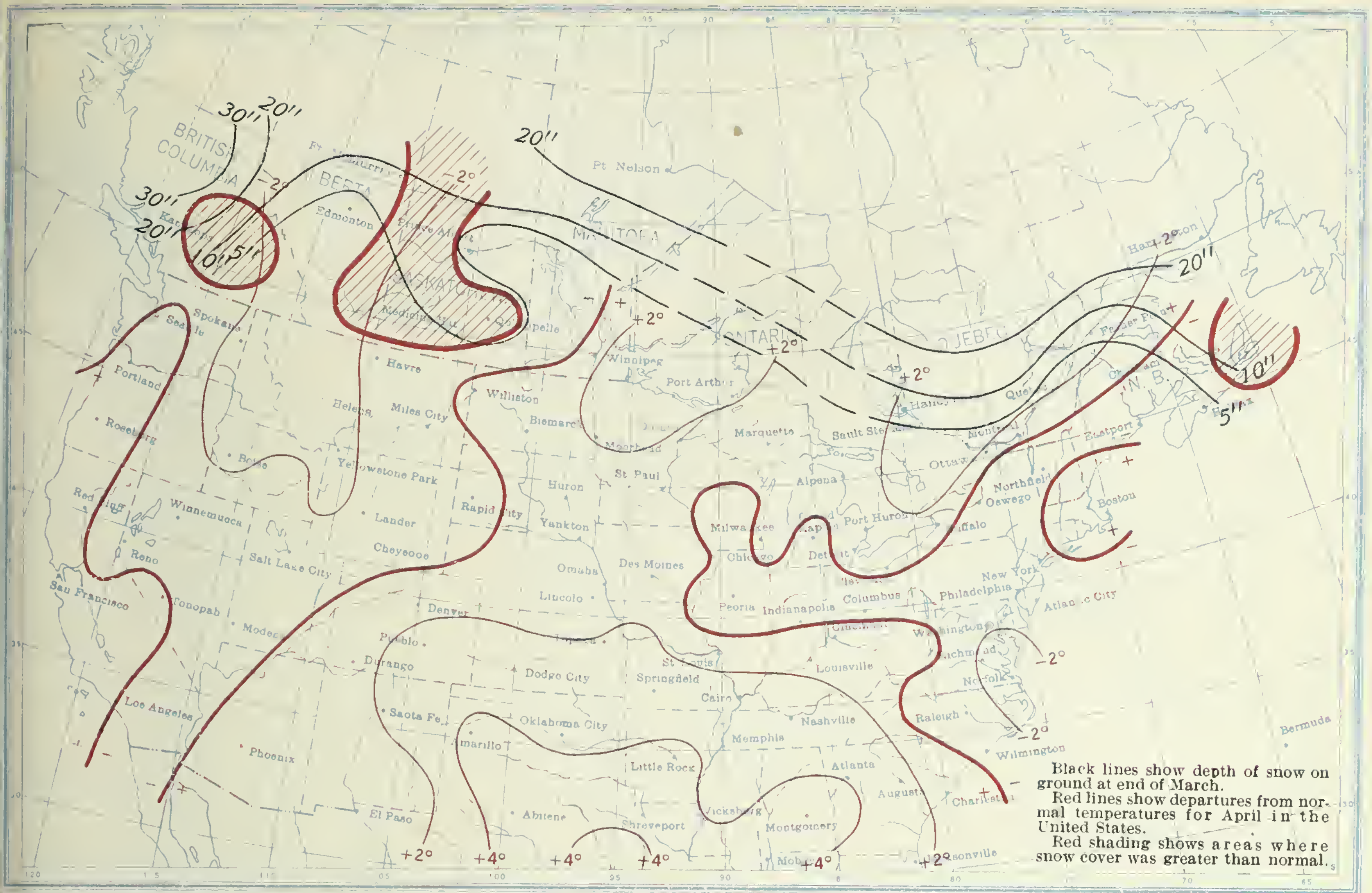
Black lines show depth of snow on ground at end of March.
Red lines show departures from normal temperatures for April in the United States.
Red shading shows areas where snow cover was greater than normal.

Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1926

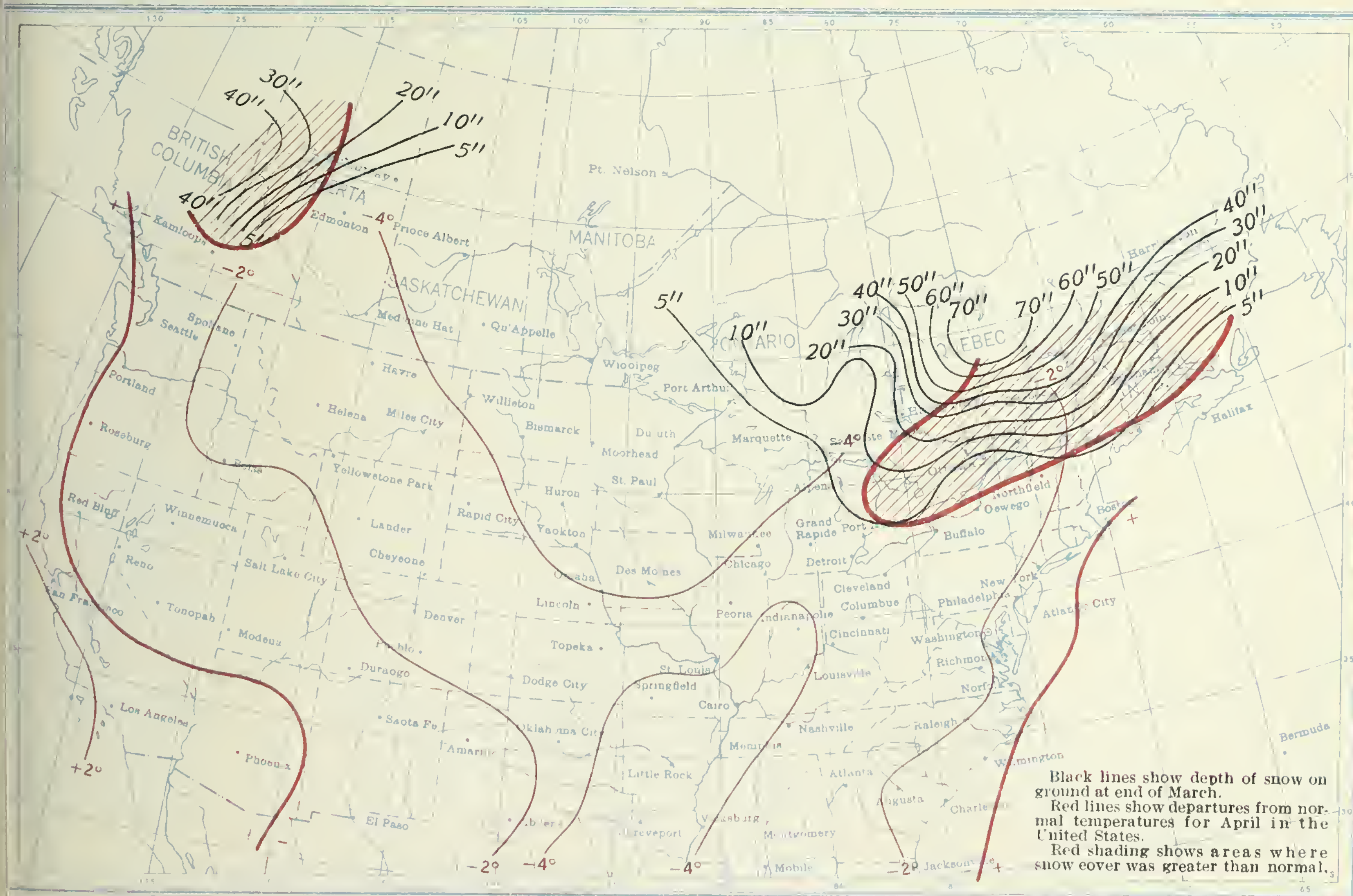


Black lines show depth of snow on ground at end of March.
Red lines show departures from normal temperatures for April in the United States.
Red shading shows areas where snow cover was greater than normal

Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1927



Snowfall Over Southern Canada at End of March and Temperature Departures in the United States for April, 1928



THE LAKE REGION

Years with April temperatures 1° or more below normal in the Lake Region, as represented by 10 well-distributed stations, were 1917 (−2.4°), 1920 (−3.7°), 1923 (−1.4°), 1926 (−5.6°) and 1928 (−2.4°).

1917.—At the end of March, a moderate snow blanket extended from the lower St. Lawrence Valley westward to the east of Lake Superior and to the North of Lake Huron, also over Saskatchewan and northern Manitoba. This condition was followed by April temperatures 2.4° below normal in the Lake Region.

1920.—Snowfall was above normal over Manitoba, central and southern Saskatchewan, and central and northern Alberta, but was considerably below normal over eastern Canada as a whole. The temperature departure for the Lake region was 3.7° below normal.

1923.—This year showed the deepest and most extensive snow cover at the end of March of any year in the period for which data are available. The region of above-normal depth extended from the Canadian Maritime Provinces westward over Quebec, Ontario, central and southern Manitoba, and Saskatchewan. Temperatures in the Lake region during April were 1.4° below normal.

1926.—Snow cover at the end of March was greater than the average in the St. Lawrence Valley, southeastern Ontario, and the Canadian Maritime Provinces. In the Lake region temperatures averaged 5.6° below normal.

1928.—The year 1928 was quite similar to that of 1926, so far as snow cover is concerned, and the temperatures in the Lake region averaged 2.4° below normal.

Of the five Aprils, with below-normal temperatures in the Lake region, three were preceded by above-normal snow cover at the end of March in Saskatchewan and Manitoba.

The years in which April temperatures were 1° or more above normal were 1921 (+7.0), 1922 (+1.5°), 1925 (+4.3°), and 1927 (+1.1°).

1921.—Snow cover was less than normal at the end of March over central and eastern Canada, being much below in the St. Lawrence Valley and in Ontario from Port Arthur eastward to Cochrane and Haileybury. The April temperature departure in the Lake region was +7.0°.

1922.—Snowfall was below normal in the St. Lawrence Valley, western Ontario, and southeastern Manitoba, being followed by a temperature departure of +1.5° in the Lake region.

1925.—Snow cover was below normal in the St. Lawrence Valley, except Quebec, in eastern Ontario, except at Cochrane, and in Saskatchewan and Manitoba, being followed by April temperatures 4.3° above normal in the Lake region.

1927.—Snow cover was below normal over Canada, except in Saskatchewan and at Kamloops and Sydney, being followed by an April temperature departure of +1.1° in the Lake region.

In all four of these warm Aprils in the Lake region, a snow cover was below normal in the St. Lawrence Valley.

We have now considered April temperatures in two areas, namely, the North Atlantic States and the Lake region, as associated with snow cover over Canada at the end of March. Let us now consider a broader territory, comprising the northeastern Rocky Mountain region, the Plains States, the Ohio, and middle and upper Mississippi Valleys, the Lake region, and the North Atlantic States. Districts 1, 3, 4, 5, and 7. (See Chart No. 1.) The most consistently cold Aprils were in order of degree of coldness, 1920 (−4.0°), 1928 (−2.4°), 1917 (−1.7°), and 1918 (−1.5°), and the most consistently warm ones in the order of warmness were 1925 (+5.2°), 1921 (+3.8°), 1922 (+1.5°), and 1927 (+1.3°).

1920.—Snowfall at the end of March was above normal in Manitoba, Saskatchewan, and part of Alberta, and below normal elsewhere in Canada, being much below over Ontario and the St. Lawrence Valley.

1928.—Snow cover was above normal in the St. Lawrence Valley, New Brunswick, and British Columbia, and below normal elsewhere in Canada.

1917.—Snowfall was above normal in the lower St. Lawrence Valley, northern Ontario, Saskatchewan, and northern Manitoba, and below normal over southeastern Manitoba and southeastern Ontario.

1918.—Snow cover over all of Canada was below normal except at Barkerville, Chatham, Halifax, and Fort McMurray.

Two of the four cold Aprils had above-normal snow cover over Saskatchewan and northern Manitoba, but no systematic relation is apparent.

1925.—Below-normal snow cover prevailed at the end of March over Saskatchewan, Manitoba, and southern Ontario, and above-normal cover over British Columbia, northern Alberta, part of northern Ontario, and at Quebec.

1921.—Snow cover was below normal over all Canada except northeastern Saskatchewan and northern Manitoba, being much below over Ontario and the St. Lawrence Valley.

1927.—Snow cover was below normal over Manitoba, northeastern Saskatchewan, Ontario, the St. Lawrence Valley, and the Canadian Maritime Provinces, and above normal in British Columbia, southern and western Saskatchewan, part of Alberta, and at Sydney.

1922.—Snow cover was mostly below normal except in portions of Saskatchewan and Manitoba and northeastern Ontario.

These four cases of warm Aprils seem quite consistent as to antecedent snow conditions, as cover over most all of Canada was below normal at the end of March in each case.

However, the author is forced to the conclusion that considering all available data from stations in southern Canada, there is little if any consistent relationship between snow cover at the end of March in southern Canada and April temperatures in our States immediately south of the Canadian border line.

It is to be regretted that depth-of-snow observations are not available from higher-latitude stations in central and eastern Canada, in which case, no doubt, more satisfactory results could have been obtained.

It seems fair to suppose that the temperatures in our northern border States are determined by several factors, at least; one of which is snow cover over Canada and while the results obtained in this study indicate quite clearly that the snow cover over southern Canada is not the main factor, nevertheless the snow cover undoubtedly has its influence.

Similar comparisons have been made between snow cover at the end of February with temperatures in northern States in March, but the results are as disappointing as those for April.

TABLE 1.—*Snow on ground at end of March*

	Dawson	Barkerville	Fort McMurray	Edmonton	Battleford	Prince Albert	Le Pas	Calgary	Medicine Hat	Swift Current	Quappelle	Minnedosa	Winnipeg	Port Nelson	Port Arthur	White River
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1916	----	----	T.	----	----	4.0	9.0	0	----	0	4.0	4.0	4.0	81.0	14.0	*18.0*
1917	----	----	----	2.0	*5.0*	8.0	9.0	0	*0*	0	8.0	T.	T.	----	5.0	30.0
1918	----	30.0	10.0	T.	*T.*	*0*	0	0	0	*0*	*0*	0	*0*	9.5	0	12.0
1919	14.0	22.0	12.0	0	*2.0*	4.0	3.0	*0*	0	0	3.0	5.0	T.	20.0	*T.*	T.
1920	22.0	3.5	5.5	6.5	8.0	6.0	*10.0*	1.5	T.	*3.0*	6.0	9.0	3.0	40.0	0	0–12
1921	22.0	25.0	6.0	0	*4.0*	10.0	10.0	0	0	*0*	0	2.0	T.	----	0.5	8.0
1922	----	26.0	16.5	----	*10.0*	11.0	7.3	----	----	----	10.0	2.0	*2.0*	12.0	*T.*	12.0
1923	42.0	44.0	11.5	T.	*T.*	T.	8.0	0	T.	*7*	16.0	22.0	9.0	2.5	15.0	38.0
1924	21.0	26.0	8.5	2.0	*1.0*	*1.0*	2.0	*T.*	0	*0*	0	T.	*T.*	----	2.2	T.
1925	30.0	55.0	5.0	4.0	*1.0*	T.	1.0	----	----	----	0	T.	T.	----	14.0	7.0
1926	14.0	----	----	T.	*T.*	0	T.	*T.*	*T.*	T.	T.	T.	T.	----	2.0	12.0
1927	13.0	30.0	13.5	2.0	6.0	2.0	2.0	----	*3.0*	*4.0*	6.0	2.0	*2.0*	26.0	T.	0–15
1928	29.0	42.0	T.	0	*1.5*	3.0	*3.0*	*T.*	0	*T.*	*T.*	T.	0	----	4.0	14.0
Average	23.0	27.6	8.0	1.5	3.2	3.8	5.0	0.2	0.3	1.3	4.1	3.5	1.5	27.3	4.4	13.5

NOTE.—Figures in italics are interpolated.

TABLE 1.—*Snow on ground at end of March*—Continued

	Cochrane	Haileybury	Stonecliffe	Parry Sound	Southampton	Ottawa	Montreal	Quebec	Father Point	Chatham	Harrington	Sydney	Halifax	Anticosti
	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1916	36.0	24.0	18.0	*12.0*	----	7.0	T.	8.0	24.0	T.	----	T.	2.0	----
1917	*32.0*	28.0	6.0	T.	0.5	T.	T.	20.0	24.0	6.0	4.0	0	T.	23.0
1918	*12.0*	----	6.0	T.	1.0	T.	3.0	18.0	*19.0*	*10.0*	42.0	T.	3.5	16.0
1919	*5.0*	15.0	6.0	*3.0*	*0*	2.5	13.0	8.0	30.0	9.0	3.0	0	T.	6.0
1920	*T.*	T.	4.0	*3.0*	2.0	0	T.	1.0	10.0	4.0	----	0	0	42.0
1921	*5.0*	T.	*T.*	*T.*	*0*	0	0	1.2	*6.0*	0	*10.0*	0	T.	12.0
1922	*22.0*	20.0	*1.0*	T.	4.0	1.0	3.0	1.8	10.0	0	----	6.0	4.0	----
1923	*40.0*	----	*20.0*	24.0	15.0	14.0	17.4	44.0	54.0	22.0	----	34.0	10.0	38.0
1924	*5.0*	----	*5.0*	6.0	5.0	1.0	1.0	28.6	*21.0*	8.0	36.0	4.0	T.	7.0
1925	*28.0*	----	*8.0*	T.	*T.*	*T.*	T.	20.0	*19.0*	T.	----	0	*0*	19.0
1926	0	----	*11.0*	10.0	3.0	*5.0*	6.0	22.0	*30.0*	12.0	----	12.0	5.0	32.0
1927	*8.0*	----	*1.0*	T.	T.	*1.0*	*2.0*	3.0	*9.0*	4.0	----	16.0	T.	18.0
1928	10.0	----	*12.0*	12.0	6.0	5.0	15.0	48.0	*30.0*	8.0	----	1.0	T.	----
Average	15.6	14.5	7.5	5.4	3.0	2.8	4.3	17.2	22.0	6.4	19.0	5.6	1.9	21.3

FLIGHT OF RS-1, SAN ANTONIO, TEX., TO SCOTT FIELD, ILL.[1]

By WILLIAM E. KEPNER, Captain, Air Corps, U. S. A.

When over Memphis we were still unable to get in touch with Scott Field. The sky to the west had been gradually thickening up. The sun was still shining where the ship was. At 1:20 p. m. there appeared a number of small rains traveling rapidly eastward across our path several miles ahead. The ship was headed about and we circled one of these with very little effect on the ship's stability. The ship was slowly circling to maneuver between several of these shower areas, when there appeared a specially favorable opening to the west. It looked as though there was a distinct wind shift line to the north and it was traveling nearly east. It was decided to fly into the apparently clear area to the west of Memphis and thus be well in rear of the squalls to the north.

Just as the ship was well on her course to the west and appeared to be running safely around the rain area, a deadly looking line squall, already perfectly developed, came racing across the sky from the northwest on a path that bid fair to interrupt the ship. To turn the ship either way was to lose time. The ship was allowed to drift slightly toward the rain on our left and the motors turned up to where the air speed was 53 miles per hour. However, the ship was being caught in the storm on our left. It was dragged rapidly in toward the center of the small disturbance and shortly afterward began to pitch and toss violently with an increasing tendency to rise in spite of even a 25° angle of descent. There was a sensation of being dragged backward and upward, with the ship out of control. There was nothing left but to run all motors at full speed. The ship was momentarily headed to the right and at an air speed of 65 miles per hour began to leave the rain squall. We were just out with a sickening plunge downward, when the line squall in the northwest appeared to be practically on top of us. This "line" was a coal-black body about 1,000 feet above the ground, with a bluish green color running underneath and all the way to the ground. From the black line great chunks of cloud were frequently thrown off, with an appearance of being immediately torn to pieces in the disturbed air just beneath. The airspeed indicator began to jump from gusts that we began at once to feel on the ship's nose. The ship would shudder as though it had bumped into something. The ship was turned as quickly as possible with such high speed, to the left and around the rear of the storm we had just left. We barely missed the northwest line squall and were in fair weather, heading southeast with the motors again throttled to cruising speed. There was a line of squalls bearing to the south, west, and northeast.

An inspection of the ship disclosed that the rigid nose had given way just where the longitudinals meet and make the nose tip. The solid cone plate, to which all girders were bolted, had broken all around and each longitudinal end was swinging free. Only two longitudinals beside the main keel structure remained solidly in place. The entire top of the nose had given way at the tip. A couple of the spacer girders that make a ring about half way back were crushed, and the nose cover was torn somewhat. The longitudinals were pushed back into place and the ends laced together with cable in an effort to approximate a new nose tip. The repair seemed satisfactory under the circumstances.

It was then 2:10 p. m. and we were traveling east. The squalls appeared to make a line across the north, west, and south. I planned to fly east and, if possible, land near Nashville, Tenn., refuel, and then outrun the storm to Langley Field, Va.

At 2:30 p. m. another line appeared across the east, and we seemed to be trapped completely. The circle of storms was about 30 miles in diameter. This was rapidly becoming less and less. When the border appeared about 5 miles away in all directions, there was a small break to the south. It was apparently our only chance, and I decided to take it. We could not afford to be caught in the center of all those approaching storms.

We moved cautiously into the opening southward. There was rain to our left and another line squall, not so well developed, on our right. With a crippled nose, it was decided to push the ship only so far as was absolutely necessary. The ship was alternately dragged first to the left, then to the right, as we would be near first one storm, then the other. When it appeared we were successfully getting through, there was an icy draft through the control car from our right, and the ship was running directly sideways to the left at an increasing

[1] Extract from official report made to Chief of Air Corps, Washington, D. C., October 18, 1928.

speed until I would estimate it to be at least 50 miles per hour. Our speed forward was 53 miles per hour. The ship was again turned to the right, but not daring to give it any more speed forward, we were unable to pull out as had been the case in the first squall. The ship was sucked rapidly into the storm on our left and quite suddenly began to rise rapidly in a very cold air that was attended by a veritable cloud-burst of water. All available valves were opened to relieve the internal pressure. As the ship soared up there was a sensation of being tossed about like a leaf, with violent shudders passing through the ship. The suspension cables on the cars shrieked with a sound similar to a diving airplane. It seemed as though something must give way in the ship's structure. The bag over the cars seemed to breathe with a great surging of gas that caused a change in the apparent cross-section shape.

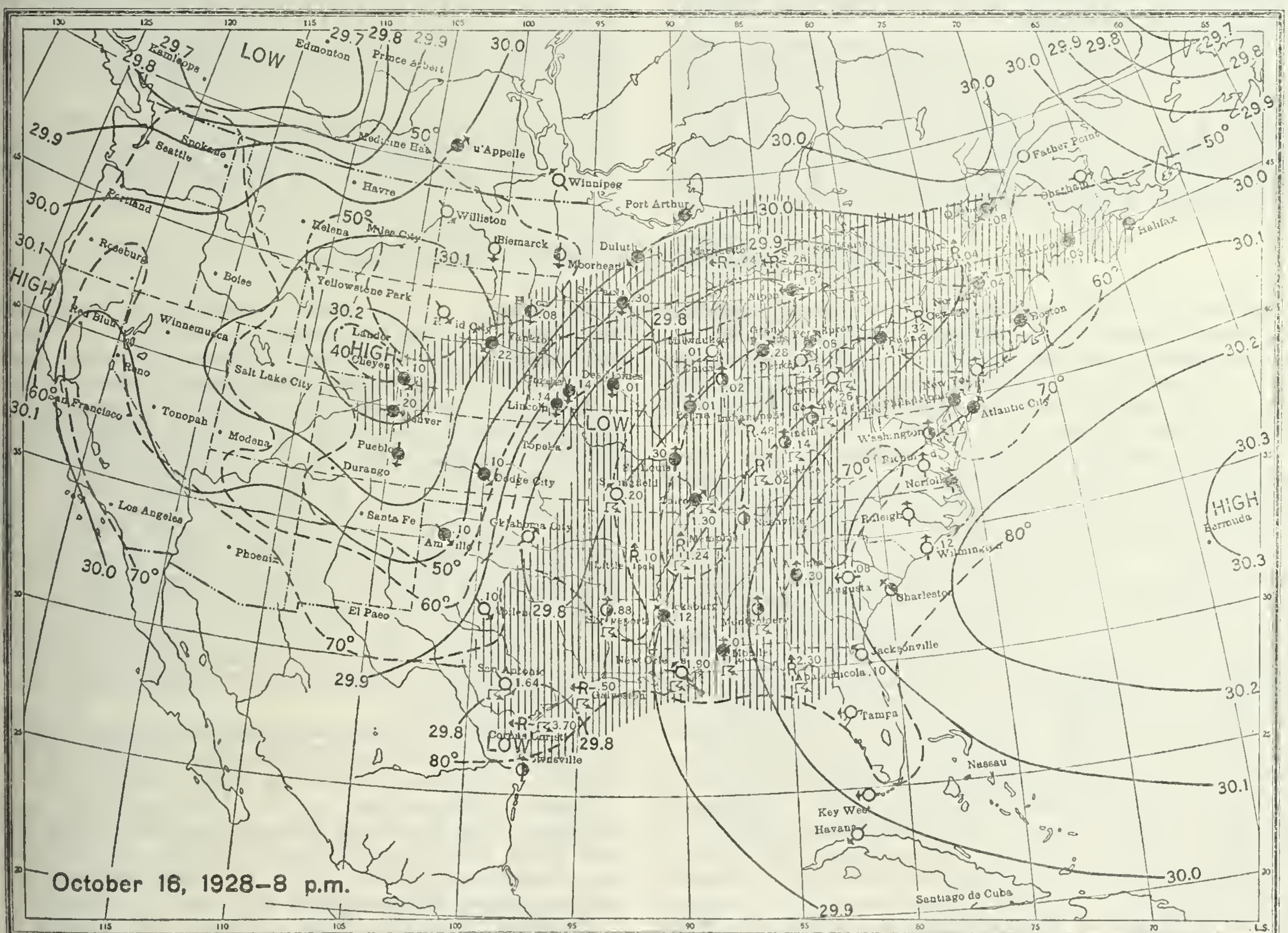
The elevators were put "hard down," and at 2,000 feet altitude the ship went into a dive of approximately 45°. Gasoline and ballast were dropped to check the fall. Everyone had to hang on, as it was impossible to stand up. All the way down the elevators were "hard up," and the ship leveled off just in time to avoid crashing. Then it immediately started rising again, very rapidly. This time it did not reach the same altitude, but repeated the dive, and again came out just in time to avoid crashing. There was apparently a blanket of very dense air on the ground that each time assisted the ship to avoid crashing. Due to our low air speed, we were not coming out of the storm very fast, and it was a battle for 15 minutes of at least six or seven sickening ascents and descents that gradually dampened out until we were finally out in a clear area to the south. We had barely reached the storm's edge when a blinding flash of lightning occurred in the center of it, and near the tail of our ship. It, however, did no damage. The wind outside this area was flowing gently from the north and a fog was forming just off the ground. The sky was clearing to the northwest, and the ship was headed in that direction. We were then 50 miles southeast of Memphis, Tenn.

An inspection of the nose showed considerable further damage. The laced ends had held, but due to the consequent flexibility, the cross bracing girders had practically all crumpled. Eight of the spacer girders had been crushed and several small holes had been punched in the gas envelope. The exposed ends of broken girders were wrapped with blankets for a padding to prevent further punctures of the gas bag. The holes were repaired. A test of flying showed that we could safely proceed at 40 miles per hour. It was then 4:30 p. m.

We received a message that conditions were favorable at Scott Field and proceeded in that direction, where we landed at 10:10 p. m., October 16, 1928.

DISCUSSION

At the time of the bad weather experienced by the *RS–1* a trough of low pressure extended from Michigan southwestward to eastern Kansas, and thence southward to the mouth of the Rio Grande. (See figure.) This trough was a part of a very extensive area of low pres-



sure that had been drifting slowly eastward for several days prior to October 16. During this period warm, humid air from the Caribbean Sea and the Gulf of Mexico had been steadily moving northward over the Mississippi Valley, while a HIGH from the Pacific Ocean had been advancing eastward over the Plateau and Rocky Mountain regions, bringing cooler air down the eastern slope of the Rockies and over western Texas by 8 a. m. of the 16th. The kite flight at Groesbeck, Tex. (started at 5:54 a. m.), shows that there had been an increase in both humidity and temperature up to 2 kilometers above the surface, and a slight decrease in temperature at the top of the flight (about 2,300 meters above the surface) since the flight 24 hours previously. This condition, increase of the lapse rate and of the humidity below the 2-kilometer level, rendered the air quite unstable and made the conditions favorable for active convection and the development of more or less violent thunderstorms a little later in the day in eastern Texas.

The air movement being from southwest to northeast, this same condition extended rapidly northeastward over Arkansas and extreme western Tennessee during the day. It was in the late afternoon that conditions quite similar to those shown by the Groesbeck kite flight set in over extreme western Tennessee and resulted in the violent thunderstorms experienced by the *RS-1*.—*Chas. L. Mitchell.*

CONICAL SNOW

By WILSON A. BENTLEY

Every late autumn and early spring there occur at Jericho, in northern Vermont, and of course at other similar locations, several falls of conical snow, and also an occasional one in winter. This sort of snow comes only out of cumulo-nimbus clouds, and more commonly when the surface temperature ranges from 34° to 44° F. Conical snowflakes have a granular texture and are built up mainly from countless undercooled cloud droplets that have frozen loosely together. Their greatest diameter ranges from one-sixth to one-third inch. The writer assumes, from a long-time study of this form of snow, that the nuclei usually, if not invariably, consist of branching tabular crystals.

It is of much interest to consider the conditions within a cumulus cloud that conspire to make the undercooled droplets so arrange themselves upon a tabular snow crystal as to form a granular snow cone. It is certain that, owing to its lightness, a tabular branching snow crystal within a cumulo-nimbus cloud, is first wafted upward and about by turbulent air currents. This causes it to become thickly coated on both sides with frozen cloud droplets, or granular snow. It now begins to fall with the denser side turned downward, and since it falls faster than the cloud droplets light granular material then rapidly collects on (is caught by) the under face thereby destroying the former gravitational equilibrium of the mass and causing it to upset, whereupon the granular snow is caught exclusively, or nearly so, by the new underside, and thus the whole converted into a more or less well-defined double cone with its abutting bases on the opposite sides of the initial tabular crystal. It is conceivable, given a cumulo-nimbus cloud of sufficient thickness, that additional upsettings might occur and thus cause the double cone to become more nearly symmetrical about its basal plane than it otherwise would be.

NOTE.—The phenomenon here described is much like, if not identical with, soft hail or graupel—free-air wads of rime, presumably, built up on snow crystals.—*Editor.*

ALFRED JUDSON HENRY, 1858–1931

Those of us who have had the privilege of watching the development of Government institutions can not fail to realize that the character of their personnel has been a potent factor in determining policies and attainments. Usually a few outstanding men have played a major part in this formative work.

The Weather Bureau has been fortunate that among its officials have been many men who sought not position but opportunity to do useful work. The subject of this notice is an outstanding example of a public benefactor of this type. Born in New Bethlehem, Pa., on September 1, 1858, he enlisted in the meteorological section of the Signal Corps, U. S. Army, in July, 1878, while in his twentieth year. Having finished the usual course of instruction in military tactics and meteorology at Fort Whipple, now Fort Myer, Va., and being exceptionally efficient as a telegraph operator, he was detailed for duty on military telegraph lines, first on the Atlantic Coast, and later on the then frontier in Texas. This was an unpleasant and difficult assignment, but in two years he had won a sergeancy, and in 1883 was called to Washington for duty in the office of the Chief Signal Office. In October, 1888, the Central Office force was given a civilian status, and from that time on Henry's advancement was rapid. In 1900 he was promoted to the position of Professor of Meteorology, and when this grade was abolished in 1910 his designation became simply Meteorologist. Later under classification of Federal employees he was advanced successively to Senior Meteorologist and Principal Meteorologist, which latter title he held until the time of his death on October 5, 1931.

Professor Henry held many important assignments, in the Weather Bureau, such as Chief of Meteorological Records Division, Chief of the River and Floods Division, Official Forecaster at Washington, in Charge of the Research Observatory at Mount Weather, Va., and finally, Editor of the Monthly Weather Review. He also was a member of numerous Weather Bureau boards that had to do with the shaping of Bureau policies.

Professor Henry was educated in the common schools, with one year in high school and one year in Reid Institute, Reidsburg, Pa. He also studied for two years at the Columbian University (now George Washington) in Washington, D. C.

He was author of several important works: "Rainfall in the United States," "Climatology of the United States"; "Weather Forecasting from synoptic charts"; "Weather Forecasting in the United States" (co-author); "The Floods of 1913 in the rivers of the Ohio and lower Mississippi Valley"; "Upper Air Investigations at Mount Weather, Va.;" and numerous papers on various phases of climatology and kindred subjects.

Professor Henry's fellow workers will cherish his memory, not alone for his scientific attainments, but

above all for himself. He was a fine type of a Christian gentleman. Generous of his time and means and of a retiring disposition, yet he always was ready to give helpful counsel to his younger associates. The writer served under and with Professor Henry for more than 40 years, a part of that time at Mount Weather, where most of the staff lived under the same roof, and in all these years neither knew nor heard of any unkind or unjust act on his part.

Professor Henry was a fellow of the American Association for the Advancement of Science, and of the American Meteorological Society. He was a member of the American Geophysical Union, and a former secretary of its Meteorological Section; a former secretary of the National Geographical Society; and a member of the American Association of Geographers, the Washington Academy of Sciences, and the Philosophical Society of Washington. He was fond of outdoor sports. In his younger days he was a base ball enthusiast and a bicylist with "century runs" to his credit. In later years golf was his recreation. He also was an amateur photographer of merit, and some of his cloud photographs have been used in cloud literature as types of the classes they represent.

In character, in industry, in loyalty, in devotion to his work, which led him to take advantage of every opportunity to prepare himself for greater usefulness, his life and its successes should be an incentive to younger men who now enjoy opportunities greater than were his. Above all they must remember that the foundation of his success was *character*.

The death of his talented daughter, Helen, in 1930, an only child, was a severe blow, from which he never fully recovered. His wife, Mrs. Jessie H. Henry, survives him.—*Herbert H. Kimball.*

PRESTON C. DAY, 1859–1931

Dr. P. C. Day was born in Frederick County, Md., October 21, 1859. He entered the Signal Corps (Weather Bureau) June 29, 1883, and after the usual six months of training at Fort Myer (formerly Fort Whipple) began his service of more than 46 years at the Central Office.

He was a man of sterling character, much liked by every one, a hard and conscientious worker, doing everything properly and on time. He was graduated from the National College of Pharmacy, Washington, D. C., on May 7, 1906.

Doctor Day was made Chief of the Climatological Division of the Weather Bureau September 12, 1910, and continued in that position until his retirement, because of ill health, on May 28, 1930. He died at his home in Washington, D. C., on October 21, 1931.

He was author of a number of papers relative to climatology, some of which are: "A Discussion of the Occurrence of Frost in the United States" (Bulletin V, of the Weather Bureau); "Relative Humidity and Vapor Pressure of the United States" (Supplement No. 6, Monthly Weather Review); "A Discussion of the Climate of the United States by Sections" (Bulletin W, of the Weather Bureau); a paper on the Climate of France and Belgium, in the Monthly Weather Review for October, 1917; a discussion of the "Cold Winter of 1917–18," Monthly Weather Review for December, 1918; and "A Treatise on the Winds in the United States," published in the Yearbook of the Department of Agriculture.

Doctor Day was editor of the Monthly Weather Review from 1910 to 1913, inclusive, editor of the National Weather and Crop Bulletin for a number of years, and editor of the Snow and Ice Bulletin from 1910 until the time of his retirement.

He was a fellow of the American Meteorological Society, and at its Washington meeting in the spring of 1926 he presented a thorough discussion of the precipitation of the Great Lakes region, a contribution that appeared in the Monthly Weather Review, March, 1926.—*M. C. Bennett.*

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C. Fitzhugh Talman, in charge of Library

RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS, OCTOBER, 1931

By HERBERT H. KIMBALL, in charge, Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged above the normal values for October at Washington and close to normal at Madison and Lincoln.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at Lincoln, Chicago, New York, Pittsburgh, and Fresno as compared with October normals for the respective stations; close to normal at Madison, and a deficit at Washington and Twin Falls.

Skylight polarization measurements made on 4 days at Washington give 63 for the mean percentage of polarization, with a maximum of 70 per cent on the 20th. At Madison, polarization measurements made on 10 days give a mean of 65 per cent with a maximum of 76 per cent on the 18th. These are above the corresponding averages for each station in October.

CORRECTION.—Owing to a misunderstanding as to the reduction factor that was required to reduce scale readings on the register to heat units the weekly averages given in Table 2 for September, 1931, for Twin Falls are too small. For the successive weeks they should read 523, 512, 398, and 464 and the departures from normal should be −9, +5, −77, and +29.

SOLAR RADIATION MEASUREMENTS AT FAIRBANKS, ALASKA

A request for the installation of apparatus for recording the intensity of solar radiation at Fairbanks was made some time ago by the agricultural experiment station at that place. It was not immediately complied with for the reason that the cover of the Weather Bureau thermoelectric pyrheliometer was secured to the metal base by cement, which did not make a permanently tight joint. Occasionally moisture condensed on the inside of the cover, which could be removed only after the instrument had been recalled to the central office.

The Eppley thermoelectric pyrheliometer is hermetically sealed inside a glass bulb, which has been carefully dried out. Little difficulty from condensation of moisture inside the bulb is therefore to be expected.

An Eppley pyrheliometer, recording on an Englehard microammeter was installed at Fairbanks early in August, 1931. It is exposed on a support 10 feet above the roof of the office building, where it has unobstructed exposure to the entire sky down to the horizon in all directions. The latitude of Fairbanks is 64° 52′ N., and the altitude of the pyrheliometer above sea level is about 500 feet.

Fairbanks is much farther north than any other station at which solar radiation measurements of this character are now systematically made. The nearest approach to it is Sloutzk, U. S. S. R., latitude 59° 41′ N. Records for the period September 4, 1927, to August 9, 1928, were, however, obtained at Green Harbor, Svalbard, latitude 78° 00′ N. They are summarized in the MONTHLY WEATHER REVIEW, April, 1931, vol. 59, p. 154. Green Harbor is well within the Arctic Circle, while Fairbanks is 1° 31′ below it. However, records from the latter station can not fail to be of interest.

The mean daily totals of radiation for each week in October are given in Table 2. The maximum daily amounts for each week are 61, 44, 42, and 40, respectively, and the corresponding hourly maxima are 11.9, 7.5, 8.1, and 7.5.

For the last three weeks in August the average daily amounts are, respectively, 322, 421, and 245, and the corresponding daily maxima are 486, 479, and 427. In September the averages for each week are, respectively, 55, 57, 40, and 46, while the maxima are 119, 103, 57, and 75. The average for the third week in August happens to be the same as the normal value for Washington for that week. All other averages are much less. In September the maximum daily amounts are less than the daily normals at any station in the United States in midwinter except in the smoky city of Chicago.

TABLE 1.—*Solar radiation intensities during October, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Oct. 3	12.24				0.86	1.19					11.38
Oct. 5	11.38	0.56	0.67	0.82	0.99						13.13
Oct. 10	7.57	0.68	0.81	0.96	1.13						7.04
Oct. 12	5.36	0.97	1.05	1.18							4.17
Oct. 13	4.37	0.59	0.95	1.09	1.15						4.37
Oct. 17	5.56	0.94	1.02	1.12	1.32						4.95
Oct. 19	5.36	0.80	0.90	1.08	1.27	1.48	1.29	1.09	0.97	0.83	4.37
Oct. 20	5.56	0.90	0.98	1.14	1.29	1.47	1.25	1.13	1.00	0.90	4.75
Oct. 21	7.04			0.78	1.02		1.00	0.72			8.18
Oct. 22	6.27	0.87	1.01	1.15	1.29	1.55	1.35	1.19	1.07	0.98	3.63
Oct. 23	6.27				1.02						6.02
Oct. 26	6.27	0.79	0.89	1.06	1.30		1.28	1.12	0.98	0.90	3.99
Means		0.79	0.92	1.04	1.15	1.42	1.23	1.05	1.00	0.90	
Departures		+0.04	+0.03	+0.09	+0.03	+0.01	+0.11	+0.11	+0.19	+0.18	

Madison, Wis.

Date	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon
Oct. 1	9.83		0.92	1.03	1.21	1.44					7.29
Oct. 2	9.83			0.81	0.97	1.26					13.13
Oct. 5	7.87						1.10				7.87
Oct. 9	6.27		0.96	1.03	1.28	1.48	1.24				7.29
Oct. 16	6.76	0.85	0.98	1.08	1.23	1.46	1.31				6.02
Oct. 17	4.95		1.11	1.22	1.38						4.75
Oct. 19	5.36						1.17				7.57
Oct. 20	7.04		0.62	0.84	1.06	1.28	1.03				8.81
Oct. 21	8.18				0.92		1.04				9.83
Oct. 24	12.24				1.31						7.29
Oct. 28	5.36	0.63	0.83	1.09	1.31						4.17
Means		(0.74)	0.90	1.01	1.19	1.38	1.15				
Departures		−0.03	−0.01	−0.03	±0.00	−0.02	−0.04				

Lincoln, Nebr.

Date	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon
Oct. 2	9.83	0.53	0.62				1.06				10.21
Oct. 4	12.24					1.42	1.19	0.98	0.85	0.74	12.24
Oct. 14	7.87	0.76		1.05							7.57
Oct. 15	7.29							1.15	1.04	0.95	8.81
Oct. 16	4.57	0.95	1.04	1.15	1.38			1.19	1.05	0.96	5.36
Oct. 17	5.79	0.47	0.70	0.90	1.27		1.31	1.18	1.03	0.93	6.02
Oct. 18	7.29						1.22	1.06	0.91	0.80	7.04
Oct. 19	9.47	0.88	0.97	1.10	1.21						11.38
Oct. 22	7.04	0.73	0.94	1.09	1.20		1.30	1.03			8.48
Oct. 23	11.81						1.19	1.07	0.91	0.80	10.21
Oct. 24	8.23							1.10	0.93	0.85	7.29
Oct. 27	3.30	0.85	0.98	1.10	1.32		1.28	1.16	1.02	0.94	4.57
Oct. 28	4.37		1.03	1.19	1.32						3.81
Means		0.74	0.90	1.08	1.28		1.22	1.10	0.97	0.87	
Departures		−0.11	−0.04	−0.02	±0.00		−0.03	+0.02	+0.02	+0.03	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

AVERAGE DAILY TOTALS

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	Fairbanks
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 1	303	280	333	310	273	394	276		445	266	474	28
Oct. 8	295	210	272	172	299	394	187		428		390	25
Oct. 15	284	290	343	292	265	338	211		378		335	28
Oct. 22	271	187	329	201	276	200	190		383		462	25
DEPARTURES FROM WEEKLY NORMLS												
Oct. 1	−26	+11	+10	+97	+14	−8	+25		+27	−75		
Oct. 8	−8	−34	−27	−22	+57	+8	−25		+34			
Oct. 15	+2	+65	+40	+114	+49	−42	+14		+12			
Oct. 22	+1	−18	+52	+41	+82	−136	+16		+51			
Accumulated departures on Oct. 28, 1931	−688	+3,311	+2,177	+1,827	+1,890	+4,822	−1,401		+1,267			

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	*h*	*m*	°	°	°			
Oct. 1 (Naval Observatory)	11	55	−40.0	309.9	+19.0		185	
			−30.5	319.4	+19.5	31		216
Oct. 2 (Naval Observatory)	10	40	−28.0	309.3	+19.0		154	
			−18.5	318.8	+19.0	25		179
Oct. 3 (Naval Observatory)	10	33	−14.0	310.2	+19.0	46		
			−5.0	319.2	+19.5	15		61
Oct. 4 (Naval Observatory)	10	41	−68.0	243.0	−9.0	62		
			−1.0	310.0	+19.0	46		
			+8.0	319.0	+20.0	6		114
Oct. 5 (Naval Observatory)	10	46	−51.0	246.7	−9.5	31		
			+12.0	309.7	+18.0	46		77
Oct. 6 (Naval Observatory)	10	48	−38.0	246.5	−10.0	15		
			+26.5	311.0	+17.0	31		46
Oct. 7 (Naval Observatory)	11	26	+40.0	311.0	+18.0	15		15
Oct. 8 (Naval Observatory)	11	20		No spots				
Oct. 9 (Naval Observatory)	10	38		No spots				
Oct. 10 (Naval Observatory)	10	37		No spots				
Oct. 11 (Naval Observatory)	10	41		No spots				
Oct. 12 (Naval Observatory)	10	48		No spots				
Oct. 13 (Naval Observatory)	10	40		No spots				
Oct. 14 (Mount Wilson)	14	15	+37.0	214.1	+1.0		10	10
Oct. 15 (Naval Observatory)	10	44		No spots				
Oct. 16 (Naval Observatory)	10	29		No spots				
Oct. 17 (Naval Observatory)	10	44		No spots				
Oct. 18 (Naval Observatory)	10	55		No spots				
Oct. 19 (Naval Observatory)	10	50	−77.0	36.0	−15.0	93		93
Oct. 20 (Naval Observatory)	10	35	−62.0	37.9	−15.0	93		93
Oct. 21 (Naval Observatory)	10	32	−50.0	36.8	−15.0	154		154
Oct. 22 (Naval Observatory)	11	5	−37.0	36.3	−16.0	154		154
Oct. 23 (Naval Observatory)	11	5	−23.5	36.6	−15.5	154		154
Oct. 24 (Naval Observatory)	10	39	−11.0	36.2	−16.0	123		123
Oct. 25 (Naval Observatory)	10	41	+2.0	35.9	−16.0	93		93
Oct. 26 (Naval Observatory)	10	35	+15.0	35.8	−16.0	123		123
Oct. 27 (Naval Observatory)	10	26	+28.0	35.7	−16.0	93		93
Oct. 28 (Mount Wilson)	11	40	+43.0	36.8	−15.5		121	121
Oct. 29 (Naval Observatory)	10	38	+56.5	37.7	−16.5	62		62
Oct. 30 (Naval Observatory)	10	34	+70.0	38.1	−17.0	62		62
Oct. 31 (Naval Observatory)	10	40		No spots				
Mean daily area for October								66

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR OCTOBER, 1931

(Data dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

October, 1931	Relative numbers	October, 1931	Relative numbers	October, 1931	Relative numbers
1	10	11	7	21	10
2	21	12	0	22	9
3	14	13	Mc 8	23	24
4	a 18	14	9	24	18
5	15	15	8	25	
6	15	16	0	26	
7	7	17	0	27	11
8	8	18	0	28	10
9	7	19	d 8	29	9
10	0	20	8	30	
				31	Wc 18

Mean: 28 days = 9.7.

a = Passage of an average-sized group through the central meridian.
c = New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in charge]

By L. T. SAMUELS

Free-air temperatures were moderately above normal at practically all levels and stations. (Table 1.) The greatest departures (between 3° and 4°) from the normal occurred at Ellendale and Omaha. Free-air relative humidities were mostly above normal at Chicago, Cleveland, and Dallas and below normal at the other stations. The greatest negative departures (−15 per cent) occurred at the 1,000 and 2,000-meter levels at Washington.

At the 1,000-meter level the resultant wind velocities were appreciably above normal at most stations, except along the Pacific Coast where they were close to normal. (Table 2.) Resultant directions were near normal at practically all stations.

At the 4,000-meter level the resultant velocities exceeded the normals at most of the northern stations. The greatest departures from the normal directions occurred at the southern stations. The normal northerly component was replaced by a westerly one over the northern Gulf region, while at Key West, the resultant direction was easterly instead of the normal westerly.

In Table 3 are shown the average and extreme heights attained and the number of flights made during the month.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during October, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (2 meters)	Omaha, Nebr.[1] (299 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)	Washington, D. C.[3] (2 meters)
Surface	11.1	10.5	17.8	15.8	9.2	16.5	11.2	20.6	20.9	12.7
500	12.0	11.6	19.4	15.9	9.5	16.6	11.8	18.9	17.7	13.9
1,000	11.1	11.2	18.8	13.6	10.3	14.3	12.2	17.2	16.2	12.6
1,500	8.8	8.5	16.1	11.0	8.2	-----	10.7	-----	-----	-----
2,000	6.6	6.2	13.6	8.8	6.2	9.7	8.5	12.8	12.5	9.1
2,500	4.0	4.0	11.3	6.2	3.7	-----	6.2	-----	-----	-----
3,000	1.3	1.6	8.6	4.0	0.7	4.3	3.3	8.1	7.3	3.9
4,000	−4.3	−3.5	2.5	−0.7	−4.8	-----	−2.9	-----	-----	1.3
5,000	−9.8	−8.7	−3.1	−7.1	−11.2	-----	−9.4	-----	-----	-----
6,000	-----	−14.2	-----	-----	-----	-----	−16.6	-----	-----	-----

RELATIVE HUMIDITY (PER CENT)

Altitude (meters) m. s. l.	Chicago	Cleveland	Dallas	Due West	Ellendale	Hampton Roads	Omaha	Pensacola	San Diego	Washington
Surface	83	81	83	70	71	80	83	81	65	78
500	74	73	71	61	68	65	76	76	65	60
1,000	67	66	63	58	55	63	64	74	57	52
1,500	61	64	60	54	51	-----	58	-----	-----	-----
2,000	55	56	56	50	45	48	53	59	44	48
2,500	51	50	50	48	45	-----	48	-----	-----	-----
3,000	51	47	45	37	45	32	50	49	36	43
4,000	49	42	40	33	47	-----	45	-----	-----	36
5,000	38	41	32	32	59	-----	43	-----	-----	-----
6,000	-----	43	-----	-----	-----	-----	43	-----	-----	-----

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during October, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 45 E	0.9	N 83 E	0.5	S 13 W	1.9	N 77 W	4.2	S 50 W	2.5	S 20 W	2.1
500	-----	---	S 43 E	5.0	S 49 W	4.8	-----	---	S 62 W	7.4	S 59 W	5.5
1,000	-----	---	S 39 E	5.2	N 81 W	6.1	-----	---	S 79 W	6.9	S 88 W	6.8
1,500	-----	---	S 48 E	4.2	N 73 W	8.5	-----	---	N 86 W	7.5	S 88 W	7.2
2,000	W	0.6	S 49 E	2.8	N 83 W	8.6	N 86 W	6.4	N 89 W	9.1	S 87 W	8.0
2,500	S 67 W	3.0	S 59 E	1.3	N 81 W	8.1	N 74 W	9.2	W	8.0	W	9.4
3,000	S 76 W	5.4	N 37 E	0.7	N 78 W	7.7	N 65 W	9.9	-----	---	N 83 W	10.1
4,000	N 84 W	9.4	N 34 W	2.8	N 54 W	9.3	N 64 W	9.3	-----	---	N 83 W	10.1
5,000	N 77 W	9.7	N 41 W	1.8	-----	---	S 81 W	10.1	-----	---	-----	---

Altitude (meters) m. s. l.	Dallas, Tex. (151 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 31 E	1.7	N 7 W	0.3	N 65 W	2.7	S 79 W	2.4	N 8 E	1.6	N 58 E	2.7
500	S 1 W	7.0	N 60 W	1.5	N 68 W	3.3	-----	---	N 55 E	4.4	N 79 E	7.2
1,000	S 17 W	7.2	N 31 W	1.1	N 65 W	5.4	S 84 W	5.7	N 75 E	2.3	S 89 E	.06
1,500	S 43 W	5.0	N 75 W	1.5	N 89 W	4.9	N 77 W	7.9	S 14 E	0.5	S 78 E	4.3
2,000	S 79 W	2.9	N 73 W	2.5	S 78 W	5.7	N 80 W	7.7	S 66 W	1.9	S 83 E	3.2
2,500	N 77 W	2.9	N 72 W	3.7	S 80 W	6.6	N 75 W	7.8	S 69 W	1.7	S 82 E	4.1
3,000	S 75 W	1.9	N 68 W	4.4	S 75 W	8.0	N 80 W	7.6	N 55 W	1.2	N 85 E	3.2
4,000	N 14 E	0.5	N 58 W	4.0	S 77 W	12.7	S 89 W	7.9	S 78 W	4.7	N 70 E	2.2
5,000	-----	---	N 71 W	5.9	-----	---	-----	---	-----	---	N 54 E	2.1

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (125 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 77 E	0.3	S 6 E	0.4	S 1 E	1.1	N 63 E	1.3	S 17 E	1.0	S 5 E	1.6
500	S 88 E	0.6	S 89 W	0.6	S 36 W	4.6	S 74 E	4.5	N 17 W	0.7	S 1 W	4.2
1,000	S 87 E	0.3	S 49 W	0.5	S 45 W	4.2	S 64 E	2.9	N 13 E	1.2	S 40 W	7.0
1,500	N 68 W	1.0	S 4 W	1.1	S 59 W	3.2	S 62 E	1.7	S 82 E	0.4	S 70 W	6.2
2,000	N 71 W	1.0	S 46 W	2.6	S 70 W	2.6	N 32 W	0.6	S 31 E	0.7	N 89 W	5.2
2,500	S 68 W	1.7	S 62 W	2.5	N 82 W	1.5	N 21 W	2.3	N 4 E	0.9	N 77 W	4.5
3,000	S 81 W	2.0	S 67 W	2.9	-----	---	N 66 W	4.1	N 54 W	3.0	N 57 W	5.8
4,000	-----	---	N 84 W	4.9	-----	---	S 86 W	6.0	N 66 W	1.6	N 40 W	4.2
5,000	-----	---	N 70 W	4.0	-----	---	S 78 W	8.1	-----	---	-----	---

Altitude (meters) m. s. l.	Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 60 W	0.3	S 69 E	1.8	S 30 E	2.7	N 44 E	0.3	S 35 E	1.4	N 49 W	0.7
500	S 59 W	2.1	S 72 E	1.4	-----	---	S 68 W	2.9	S 24 W	3.0	N 72 W	5.2
1,000	S 69 W	5.4	S 78 E	1.0	-----	---	N 80 W	6.9	S 25 W	3.2	N 68 W	5.6
1,500	S 83 W	7.4	S 5 E	1.5	S 16 E	3.7	N 79 W	8.4	S 37 W	4.0	N 61 W	7.2
2,000	N 86 W	7.5	S 15 W	3.3	S 4 W	3.5	N 74 W	10.0	S 40 W	3.2	N 70 W	8.0
2,500	N 85 W	8.1	S 32 W	5.2	S 41 W	2.5	N 70 W	11.0	S 21 W	2.5	N 70 W	9.8
3,000	N 85 W	7.4	S 45 W	6.3	S 58 W	4.1	N 80 W	11.2	N 32 E	1.7	N 75 W	9.9
4,000	-----	---	S 55 W	12.7	S 68 W	5.9	-----	---	-----	---	-----	---
5,000	-----	---	-----	---	N 82 W	9.0	-----	---	-----	---	-----	---

TABLE 3.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during October, 1931*

	Dallas, Tex.[1]	Due West, S. C.	Ellendale, N. Dak.	Chicago, Ill.[1]	Cleveland, Ohio[1]	Omaha, Nebr.[1]
Mean altitudes, meters, m. s. l., reached during month	5,416	3,010	3,493	4,775	5,742	6,317
Maximum altitude, meters, m. s. l., reached	5,763	[2] 5,477	[3] 5,682	5,284	6,329	6,712
Number of flights made	31	31	27	31	31	32
Number of days on which flights were made	31	31	26	31	31	31

[1] Airplanes. [2] Limited-height sounding balloon. Kite.

WEATHER IN THE UNITED STATES

[The Climatological Division, OLIVER L. FASSIG, in Charge]

THE WEATHER ELEMENTS

By M. C. BENNETT

The month of October, as a whole, was warmer than normal in all sections of the country except a small area along the Pacific coast. The warmest weather occurred between the Appalachian and Rocky Mountains where the average for the month was generally from 4° to 7° above the normal. In large portions of the country where killing frost or freezing temperature almost invariably occurs before the end of October, this month ended without such occurrence, and the same was true of snowfall.

The precipitation during the month was scanty in most sections. A rather large area extending from the central portion of Indiana, Illinois, and Missouri northward received more than normal, some stations reporting one and one-half times the usual amount for October. The north Pacific and central Rocky Mountain areas also received rather generous falls, while in much of the east and south, except locally, the month was dry, many stations receiving less than 25 per cent of the normal. The far Southwest from New Mexico to the Pacific likewise received only about 25 per cent of the monthly average.

TEMPERATURE

October temperatures were decidedly like those of the September which had just preceded. Again only portions of the Pacific States averaged cooler than normal, and those portions but slightly. Most of the country, especially between the Rocky Mountains and the upper Lakes and lower Mississippi River, was decidedly warmer than normal. Warm weather prevailed nearly everywhere during most of the opening decade, notably from the middle and northern Plains to the upper Lakes. About the close of this decade cooler weather reached the far Northwest and the first part of the second decade was colder than normal in most northern and far-Western districts. The latter part of the second decade was featured by several comparatively cool days from the upper Mississippi Valley eastward and southeastward. Meantime warmth had prevailed in the greater part of the country, especially the Southwest.

The final decade was remarkable for high temperatures practically everywhere east of the Rocky Mountains until about the 28th, when cold weather reached the northern portions of the Plains and Rocky Mountain regions, whence it advanced southeastward so that the month closed with comparatively low temperatures prevailing in the central valleys and the Gulf States.

As a whole the month averaged slightly colder than normal in parts of the Pacific States, but elsewhere warmer. In much of Texas and the southern Plains it was the warmest October of record, and usually between the Rocky and Appalachian ranges the average excess was 4° to 7°. In the North Atlantic States the excess was but about 3° and near the south Atlantic coast less than 2°.

A temperature of 105° was noted in western Texas on the 6th. In most States the highest readings reported were between 90° and 100°, but in a few States, chiefly along the northern boundary, they were from 90° to 85° or slightly less. In nearly all States the highest readings occurred during the first decade.

The lowest reading reported was 7° below zero at a high station in Colorado on the 30th. Most States of the western half noted readings lower than 20°, also most northern border States to eastward, and some points in the middle and southern Appalachians. In nearly all States of the Ohio and Mississippi Valleys and in parts of the Southeast there were no readings lower than 25°. From the upper Mississippi Valley eastward and southeastward the lowest marks occurred chiefly during the middle decade, particularly about the 19th, but from the Plateau to the Plains and in the lower Mississippi Valley they usually occurred just before the month ended.

PRECIPITATION

As in September, the rainfall of October, 1931, was plentiful in much of the north-central portion and usually in the middle Rocky Mountain area, while it was very scanty in the Southeast and generally somewhat less than normal in the North and Middle Atlantic States, the Plains region, and the middle and northwestern Plateau area.

The first three weeks were decidedly dry in the Southeast, save southern Florida and a few other limited areas. Some portions of the Plains and most of the middle and upper Mississippi Valley and the western part of the Lake region had important rainfall during the second week of the month.

The final decade brought the most important rainfall of the month. There was much rain in the far Northwest, and in Wyoming and adjacent areas; likewise most districts from the Dakotas eastward to the north Atlantic coast and considerable parts of the Ohio and lower Mississippi Valleys and the near Southwest had moderate to liberal rainfall.

Only about one-third of the States had rainfall greater than normal for October, and in these the amounts were only moderately large. Much of the north-central portion of the country received somewhat more than normal, Illinois and Indiana averaging almost 4 inches, or an excess of over one-third the normal amounts. Smaller departures above normal were noted in the Pacific Northwest and a few other areas. The eastern and central portions of Oklahoma, with much of northern Texas and western Arkansas, received a considerable excess, as did some parts of Florida and southeastern Louisiana.

In the entire country the greatest amount for the month so far reported was 15.27 inches, at a station in western Washington. East of the Pacific States the greatest amount was 13.44 inches, at Burrwood, La.

From Pennsylvania southward there was a notable shortage in the Atlantic States, South Carolina receiving but four-fifths of an inch, on the average, or but about one-quarter of normal. At Charleston this was the sixteenth consecutive month to bring less than normal rainfall. Most of the East Gulf States, the lower Mississippi and upper Ohio Valleys, and southeastern and central Texas measured far less rain than normal; and there was a decided shortage in the greater part of the Rio Grande Valley, the western Plains, Montana, and the northern and western Plateau area.

SNOWFALL

The snowfall was decidedly light compared with the average amounts for October. Particularly from the central part of the Lake region westward over northern districts almost to the Rocky Mountains there was either no snow or merely negligible amounts, the greater part of the Missouri Valley reporting a few flurries during the final week. From northern New York southwestward to the central Appalachians there was a little snow just after the middle of the month.

From the Rocky Mountain States westward to beyond the Cascade-Sierra crest there was snowfall over considerable areas, though usually only at the higher elevations. This occurred almost wholly during the last fortnight of the month, and was generally of small amount, though there was a monthly fall of 52 inches at Mount Baker Lodge, in Washington.

SUNSHINE AND RELATIVE HUMIDITY

More than the usual amount of sunshine was received over much of the Atlantic Coast States, the upper Mississippi and upper Missouri Valleys and portions of Oklahoma, northern Texas, and southern New Mexico. Less than the normal amount was received in the upper Ohio, central Mississippi, and lower Missouri Valleys. Elsewhere it was generally near the average.

The relative humidity was above the normal in much of the Ohio, the central and upper Mississippi, and lower Missouri Valleys, in portions of the central Rocky Mountains and southern Plateau regions and locally in central Texas and on the Gulf coast. Elsewhere it was generally below the average, but in most sections the departures therefrom were small.

SEVERE LOCAL STORMS, OCTOBER, 1931

The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)[1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Crawford, Fremont, and Madison Counties, Iowa.	6					Rain and flood	Lowlands inundated; considerable damage to crops, dirt roads, and sewers.	Official U. S. Weather Bureau.
Seneca and Crawford Counties, Ohio.	6					Floods	Crops, roads, and bridges damaged	Do.
Marshall County, Iowa	7	12:15 a. m.			$2,300	Wind	Crops, windmills, and garages damaged	Do.
Rotan (near), Tex	7	4 p. m.	1,760		500	Tornado	50 bales of cotton destroyed; 2 persons injured	
Terre Haute (near), Ind	7	5:53 p. m.			16,000	Electrical	Dwelling burned and paper mill damaged by lightning.	Do.
Ames, Iowa	7	P. m.			52,505	do	Cattle barn at Iowa State College destroyed	Do.
Fort Mills, S. C	9	6 p. m.	1,300		4,000	Small tornado	Crops and farm buildings damaged; path 1 mile long.	Do.
Honea Path (near) to Due West (near), S. C.	9	9 p. m.	1,320		6,000	Hail	Much cottonseed destroyed; 150 bales of cotton damaged; path 12 miles long.	Do.
Gramling, S. C	9	P. m.			2,000	Thunderstorm	Schoolhouse damaged by lightning	Do.
Shelby County, Iowa	10	4:30-5 p. m.			25,000	Rain, hail, and wind.	Glass in buildings and greenhouses broken; poultry killed; trees damaged; path 10 miles long.	Do.
Norton, Phillips, and Sheridan Counties, Kans.	10	5:30-7 p. m.	20 mi.			Hail and wind	Corn damaged 90 per cent in places; small farm buildings, implements, and windmills damaged; 2 persons injured; path, 65 miles long.	Do.
Marshall County, Iowa	10	7-8 p. m.				Rain, hail, wind, and electrical.	Considerable damage to roofs, farm buildings, and trees; poultry killed; electric, power, and telephone services crippled.	Do.
Cloud, Jewell, Republic, and Washington Counties, Kans.	10	8 p. m.	10 mi.		15,000	Violent wind	Damage chiefly to farm buildings, livestock, and telephone lines; path, 40 miles long.	Do.
Bureau, Carroll, and La Salle Counties, Ill.	10	P. m.				Rain and flood	Pavements damaged; railroad beds washed out; basements flooded; crops hurt; some loss of livestock.	Do.
Cass and Pottawatamie Counties, Iowa.	10	do				Wind and rain	Farm buildings, windmills, and trees damaged; several buildings moved on foundations; 1 person injured.	Do.
Clinton and Jackson Counties, Iowa.	10	do				Rain and flood	Lowlands inundated; minor railroad washouts; 10 small bridges wrecked; basements flooded.	Do.
Freemont County, Iowa	11	5:50-10:30 p. m.				Wind	Trees, roofs, and outbuildings damaged	Do.
Colby (near), Kans	11	7 p. m.				Hail	Chief damage to corn and other feed crops	Do.
Shreveport, La. (7 miles southeast).	15	1:50 p. m.			$500	Tornado	Character of damage not reported; path 3 miles long.	Do.
Gouverneur (near), N. Y.	25				3,000	Thunderstorm	Farmhouse struck by lightning and burned	Do.
Quincy, Ill	25	A. m.			1,500	Rain and flood	Basements flooded; sewers and sidewalks damaged; traffic delayed.	Do.
Wyoming (eastern half)	26-29					Wind	Poles blown down; many miles of fences damaged or destroyed; store windows broken in Cheyenne.	Do.
Somerset (near), Tex	29	4:30 p. m.	1,760		75,000	Tornado	75 oil derricks damaged; minor damage to other property.	Do.

[1] "Mi." signifies miles instead of yards.

RIVERS AND FLOODS

By RICHMOND T. ZOCH

[River and Flood Division, Montrose W. Hayes in charge]

Heavy local rains in Crawford County, Ohio, on the 6th, caused creeks to overflow, doing damage estimated at $1,200.

The only river flood was in the Grand, in northcentral Missouri. It was of very minor importance and the attendant damage was estimated at only $100.

Table of flood stages in October, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM					
Missouri Basin					
Grand:	Feet			Feet	
Gallatin, Mo	20	12	13	24.1	12
Chillicothe, Mo	18	12	14	21.2	13

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By the Marine Division, W. F. McDONALD in charge]

NORTH ATLANTIC OCEAN

By W. F. McDONALD

The pressure situation.—The first half of October, 1931, over the North Atlantic Ocean and adjacent continental areas was characterized by a pressure distribution which was quite stable in its large outlines. An extensive but moderate HIGH dominated the Atlantic between the United States and Spain, but a series of LOWS maintained a pressure trough from Labrador to northern Scandinavia during the first two weeks of the month. In general the track of the centers of individual LOWS was similar to that followed by the disturbances of the latter part of September and including that period there was about five weeks of remarkably persistent pressure distribution.

In the middle of October, however, there was a decided change in the pressure situation beginning with the development of a minor tropical disturbance about the 13th over the Bahama group. Immediately thereafter, a LOW appeared suddenly in mid-Atlantic near the Azores, and an extensive trough formed simultaneously, extending from the Florida Straits northward to Hudson Strait. This developed into a deep LOW off the middle Atlantic coast in the next few days.

After the 16th, a succession of well-developed low-pressure areas crossed the Altantic between latitudes 30° and 50° N., with the result that the normal ocean high-pressure area was disrupted. During the last half of the month, HIGHS were more transitory, and the only stable high-pressure conditions prevailed over the far northern portion of the ocean and along the European coast.

The resultant barometric averages for the month as a whole (see Table 1) revealed again, as in the previous month, above-normal pressures in the northeastern Atlantic, but central in this case over the British Isles. There was a deficiency from the Azores to New England and also from the Azores southwestward over the Caribbean Sea, with a slight excess of pressure over the Gulf of Mexico.

Gales and disturbances.—Gales were reported on the Atlantic on 22 days in October, and winds of gale force at some time in the month from nearly every part of the ocean north of a line from Turks Island to Lisbon. A few days at the opening and at the close of the month were comparatively quiet. Two to three day intervals on the 12–13th, 15–17th, 21–22d, and 26–28th, comprised the most widespread storminess, the 12–13th being perhaps the most disturbed period. On the latter dates, gales were encountered (well off the American coast) from latitude 30° northeastward to mid-Atlantic in latitude 40°. Winds of hurricane force were experienced on the 13th by the German ship *New York*, enroute westward near latitude 45° N., longitude 43° W. This was the highest wind reported during the month.

Gales of force 11 were reported on several dates from the main trans-Atlantic steamer route, and whole gales with some frequency between the 9th and 22d. Shipping was but slightly hampered, however, and no major damage to marine commerce has been reported, although several small ships were in distress, and the 100-ton motor ship *Canusa* (British) was lost near the Bahamas about the 15th.

Two barometric depressions, apparently weak tropical disturbances in origin, appeared over the region of the Bahamas, the first between the 12th and 15th and the second about a week later. The first development produced no high winds so far as reports in hand indicate, but the second caused moderate to fresh gales on the 20th and 22d as it moved northeastward into the middle-western part of the Atlantic.

The latter storm development appears to have been the major factor in producing the predominant cyclonic conditions of the last decade of October. Its progress at successive stages is shown in four charts (VIII to XI) dated at 2-day intervals during the life of the disturbance, beginning with October 22.

Fog.—There was some increase as compared with fogs in September, but fogginess was not seriously prevalent at any period in October. As usual, the most frequent reports of this condition came from the areas around the Grand Banks, but even there the prevalence was less than 25 per cent. A few scattered fogs were encountered well southward in the western Atlantic, towards Bermuda, and similar conditions in the eastern Atlantic as far southward as the offing of the Straits of Gibraltar.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, October, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland [1]	29.87	----------	30.55	17th	29.10	13th.
Reykjavik, Iceland [1]	29.65	−0.03	30.68	20th	28.71	2d.
Lerwick, Shetland Isles [1]	29.85	+0.06	30.52	18th	29.25	8th.
Valentia, Ireland [1]	30.12	+0.21	30.62	14th	29.59	23d.
Lisbon, Portugal [1]	30.09	+0.07	30.38	2d	29.50	24th.
Madeira [1]	30.03	+0.05	30.25	11th	29.82	22d.
Horta, Azores [1]	29.98	−0.13	30.39	7th	29.27	22d.
Belle Isle, Newfoundland [1]	29.94	+0.07	30.36	12th	29.28	2d.
Halifax, Nova Scotia [1]	29.96	−0.08	30.34	1st	29.38	26th
Nantucket [2]	30.00	−0.05	30.41	13th	29.34	16th.
Hatteras [2]	30.11	+0.05	30.47	1st	29.64	16th.
Bermuda [1]	30.07	0.00	30.26	14th	29.76	16th.
Turks Island [1]	30.00	−0.05	30.08	30th	29.88	4th.
Key West [2]	29.97	+0.03	30.14	1st	29.81	17th.
New Orleans [2]	30.06	+0.03	30.30	1st	29.79	28th.
Cape Gracias [1]	29.83	−0.09	29.94	1st	29.76	18th.

[1] All data based on a. m. observations only, with departure computed from best available normals related to time of observation.

[2] Corrected 24-hour means, based on more than one observation daily.

OCEAN GALES AND STORMS, OCTOBER, 1931

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Makiki, Am. S. S.	Mobile	San Pedro	28 06 N	87 13 W	Oct. 1	8 p., 1	Oct. 2	30.09	NE	NE, 7	ENE	E, 8	E-NE-E.
Ala., Am. S. S.	Antwerp	Baltimore	42 18 N	65 00 W	do	Noon, 2	do	30.02	SW	SW, 8	SW	SW, 8	Steady.
Maravi, Pan. S. S.	Preston, Cuba.	Boston	29 35 N	73 06 W	Oct. 3	8 p., 3	Oct. 4	30.10	ENE	ENE, 8	E	ENE, 8	ENE-E.
Dresden, Ger. S. S.	Bremerhaven	New York	50 15 N	24 53 W	Oct. 5	5 p., 5	Oct. 8	29.70	WNW	WNW, 8	NW	WNW, 10	WNW-NW.
Maine, Dan. S. S.	Swansea	Montreal	53 34 N	23 26 W	do	4 a., 6	Oct. 7	29.50	SSW	W, —	WNW	W, 10	
Winnebago, Br. S. S.	River Tyne	Philadelphia	58 35 N	10 20 W	do	4 p., 6	Oct. 10	29.07	SW	SW, 7	SW	—, 9	SW-W.
Saco, Am. S. S.	Antwerp	Boston	48 56 N	32 27 W	Oct. 7	11 p., 7	do	29.70	SSW	SSW, 7	W	WNW, 9	
Tiger, Nor. S. S.	Bergen	Baton Rouge	58 56 N	15 00 W	Oct. 8	9 p., 9	Oct. 11	29.12	SW	WSW, 9	WSW	WSW, 11	S-SW-W.
Cameronia, Br. S. S.	New York	Glasgow	55 33 N	16 07 W	Oct. 10	Noon, 10	Oct. 10	29.81	SW	SW, 9	W	SW, 9	Steady.
Carabobo, Am. S. S.	do	La Guaira	24 15 N	67 10 W	Oct. 11	1 a., 11	Oct. 12	30.04	SE	SE, —	SE	—, 8	SE-S.
Milwaukee, Ger. S. S.	Cobh	New York	42 23 N	58 15 W	Oct. 12	8 a., 12	Oct. 13	29.66	SSE	W, 5	NW	WNW, 9	W-NW.
Sinaia, Fr. S. S.	Gibraltar	Providence	39 10 N	62 05 W	do	10 a., 12	do	29.77	SSW	WSW, 9	NW	—, 9	
W. C. Teagle, Am. S. S.	Baytown	New York	38 10 N	74 25 W	do	—, 12	Oct. 12		N	N, 8	N, 3	—, 8	
Tiger, Nor. S. S.	Bergen	Baton Rouge	56 01 N	31 50 W	Oct. 13	4 p., 13	Oct. 14	29.72	SSW	SSW, 10	SW	SSW, 10	SSW-SW.
New York, Ger. S. S.	Cherbourg	New York	45 20 N	43 00 W	do	—, 13	Oct. 13	29.21	SSE	SE, 12	W	SE, 12	
Excambion, Am. S. S.	New York	Gibraltar	38 00 N	13 20 W	Oct. 12	4 a., 14	Oct. 14	30.05	N	ENE, 8	NE	NE, 9	Steady.
City of Alton, Am. S. S.	Rotterdam	New York	50 15 N	29 10 W	do	4 a., 15	Oct. 15	29.83	NW	SW, 8	NW	S, 9	Do.
Maravi, Pan. S. S.	Boston	Preston, Cuba.	28 55 N	73 20 W	Oct. 15	5 p., 15	do	29.62	S	SW, 7	WNW	S, 8	S-SW-W.
Dresden, Ger. S. S.	New York	Bremerhaven	41 18 N	65 30 W	do	8 p., 16	Oct. 16	29.24	SE	S, 10	S	S, 10	
Greystoke Castle, Br. M. S.	Port Said	New York	37 26 N	58 18 W	do	7 a., 17	Oct. 17	29.69	ESE	S, —	W	SE, 9	SE-S.
Davisian, Br. S. S.	San Juan	Havre	41 40 N	34 57 W	do	4 p., 17	Oct. 18	29.26	NW	WSW, 6	ESE	S, 9	
Changuinola, Br. S. S.	Jamaica	Avonmouth	39 00 N	36 33 W	Oct. 17	4 a., 19	Oct. 19	29.40	NW	NNW, 6	NE	NNW, 8	NNW-N-NE.
El Almirante, Am. S. S.	New Orleans	New York	25 20 N	80 12 W	Oct. 19	8 p., 19	Oct. 20	29.86	NE	NE, 8	NE	NE, 8	Steady.
Davisian, Br. S. S.	San Juan	Havre	47 28 N	17 14 W	Oct. 20	Noon, 21	Oct. 21	29.39	E	ESE, 7	E	—, 9	E-ESE.
Davenport, Am. S. S.	Antwerp	Tampa	39 21 N	27 30 W	Oct. 21	8 p., 21	Oct. 23	29.21	S	S, 4	WSW	SSW, 9	W-SSW-WSW
Southern Prince, Br. M. S.	Rio de Janeiro.	New York	27 23 N	66 58 W	Oct. 20	5 a., 21	Oct. 21	29.47	S	W, 7	NNE	N, 9	W-NW-N.
West Chetac, Am. S. S.	St. Vincent	New Orleans	25 34 N	61 38 W	Oct. 21	4 p., 21	Oct. 22	29.65	SSW	SW, 8	N	—, 8	SW-W.
British Lantern, Br. S. S.	Port Arthur	Montreal	38 31 N	68 07 W	Oct. 22	4 p., 22	Oct. 24	29.91	NW	NW, 10	NNE	NW, 10	
West Totant, Am. S. S.	Manchester	New Orleans	30 00 N	53 25 W	Oct. 21	10 a., 22	Oct. 22	29.50	WSW	SW, 10	WNW	SW, 10	SW-NNW.
Dresden, Ger. S. S.	New York	Bremerhaven	51 48 N	25 18 W	do	8 a., 22	do	29.59	ENE	ENE, 10	ENE	ENE, 10	Steady.
Independence Hall, Am. S. S.	Bordeaux	New York	43 54 N	55 45 W	Oct. 22	9 p., 22	Oct. 24	29.62	NE	NE, 7	NE	NE, 9	Do.
New York, Ger. S. S.	New York	Cherbourg	43 18 N	48 00 W	do	Noon, 25	Oct. 25	29.12	NNW	NNW, 7	E	NE, 10	NNW-E.
Sundance, Am. S. S.	Hamburg	Jacksonville	42 50 N	62 54 W	Oct. 27	—, 27	Oct. 30	29.28	NW	WSW, —	SW	SW, 9	WSW-NW.
Norwegian, Br. S. S.	Liverpool	New Orleans	37 44 N	44 12 W	Oct. 28	Noon, 28	Oct. 29	29.74	SW	SW, 8	NW	—, 8	WSW-NW.
Lepanto, Br. S. S.	Hull	Boston	46 26 N	41 10 W	Oct. 29	9 a., 29	Oct. 30	29.47	W	W, 5	WNW	NW, 8	W-NW.
NORTH PACIFIC OCEAN													
Pres. Cleveland, Am. S. S.	Seattle	Yokohama	52 10 N	151 05 W	Oct. 6	8 p., 6	Oct. 7	29.98	S	SSW, 9	WSW	SSW, 9	S-SW-WSW.
Do	do	do	48 08 N	168 36 E	Oct. 8	2 a., 13	Oct. 14	29.40	SW	W, 9	W	W, 9	SE-W-NW.
Emp. of Asia, Can. S. S.	Yokohama	Vancouver	50 34 N	158 09 W	do	4 a., 9	Oct. 9	29.71	SW	WSW, 7	WSW	SW, 8	SW-WSW.
City of Victoria, Can. S. S.	Osaka	America	34 39 N	140 08E	Oct. 9	4 p., 10	Oct. 10	29.45	NE	N, 9	N	N, 9	
Achilles, Br. S. S.	Singapore	Hong Kong	[1]17 30 N	113 43 E	do	8.30 a., 10	Oct. 11			Calm		—, 12	
Wisconsin, Am. S. S.	Dairen	San Francisco	47 45 N	161 00 W	Oct. 10	10 p., 10	do	29.36	SSW	SSW, 8	WSW	SSW, 9	
Yokohama Maru, Jap. S. S.	Yokohama	Victoria	50 08 N	147 44 W	do	Noon, 11	do	29.26	SSW	SSW, 8	SW	SSW, 9	Steady.
Amalthus, Br. S. S.	Kobe	San Pedro	36 45 N	144 00 E	do	Mdt., 10	do	29.11	NE	NE, —	NW	N, 9	E-NE-N.
Victoria, Am. S. S.	Seattle	Nome	51 28 N	141 36 W	Oct. 11	6 a., 11	Oct. 14		S	S, 9	NNE	S, 9	
Golden Tide, Am. S. S.	Hong Kong	San Francisco	47 41 N	179 21 W	do	10 p., 16	Oct. 16	28.36	SSE	SW, 7	WNW	WNW, 11	
Alaska, Am. S. S.	Seattle	Seward	60 00 N	145 45 W	Oct. 12	1 a., 12	Oct. 12	29.13	E	E, 8		ENE, 8	E-ENE.
Golden Sun, Am. S. S.	San Francisco	Yokohama	44 29 N	164 25 E	do	Noon, 12	Oct. 13	29.54	SSW	SW, 7	WNW	NNW, 9	SW-W-NW.
Do	do	do	42 50 N	157 20 E	Oct. 14	7 a., 15	Oct. 15	29.00	S	NW, 10	NNW	NW, 10	SW-W-NW.
Pres. Cleveland, Am. S. S.	Victoria	do	44 25 N	155 59 E	do	12 p., 14	do	29.02	SW	E, 4	NW	NNW, 9	SE-E-NNW.
Pres. Jefferson, Am. S. S.	Yokohama	Victoria	48 17 N	175 10 E	Oct. 15	6 a., 16	Oct. 16	28.55	E	NNW, 7	NW	NW, 9	SSW-NNW.
Silvercypress, Br. M. S.	San Francisco	Yokohama	42 35 N	180 00	Oct. 16	Mdt	do	29.19	SW	SSW, —	WNW	WSW, 9	S-WSW.
Sierra, Am. S. S.	do	Pago Pago	33 10 N	122 01 W	Oct. 17		Oct. 18	29.97	NW		NNW	NW, 8	NW-NNW.
Golden Wall, Am. S. S.	Hong Kong	San Francisco	22 20 N	125 25 E	do	4 a., 18	do	29.69	NE	ENE, 8	ENE	NE, 8	ENE-E.
Winnipeg, Fr. S. S.	San Pedro	Portland	Arena	Point	Oct. 18	—, 18	Oct. 19	[2]29.78	NW	NW, 7	N	NNW, 8	
Golden Tide, Am. S. S.	Hong Kong	San Francisco	46 58 N	158 26 W	Oct. 19	8 a., 20	Oct. 20	29.81	SW	WSW, 9	WNW	SW, 9	
Pres. Taft, Am. S. S.	Victoria	Yokohama	51 56 N	152 15 W	Oct. 20	8 p., 20	Oct. 22	28.87	S	WNW, 10	NW	WNW, 10	W-WNW-NW
Melville Dollar, Am. S. S.	Everett	Shanghai	35 08 N	161 57 E	Oct. 21	4 a., 21	Oct. 21	29.80	SSW	SSW, 7	NNE	—, 9	
Pres. Taft, Am. S. S.	Victoria	Yokohama	50 59 N	178 16 W	Oct. 25	Noon, 25	Oct. 26	29.35	SSW	E, 8	NNW	E, 8	ESE-E-NNE.
Golden Wall, Am. S. S.	Hong Kong	San Francisco	36 30 N	148 20 E	Oct. 26	10 a., 27	Oct. 27	29.59	S	E, 7	N	N, 8	S-E-NE.
Melville Dollar, Am. S. S.	Everett	Shanghai	41 24 N	166 40 W	Oct. 27	Noon, 27	do	29.85	NW	NW, 9	NW	NW, 9	Steady.
Kentucky, Am. S. S.	Legaspi	San Francisco	43 14 N	142 25 W	Oct. 28	6 a., 28	Oct. 28	29.60	S	S, 8	SW	S, 8	S-SW.
Hakushika Maru, Jap. S. S.	Miike	Port Townsend.	44 06 N	160 02 E	Oct. 27	1 a., 28	do	[2]29.22	SE	SSE, 8	NW	SE, 10	SE-NE.
Do	do	do	46 03 N	171 40 E	Oct. 29	8 a., 30	Oct. 30	[2]29.22	SSE	W, 9	W	W, 10	WSW-W.
Victoria, Am. S. S.	Seattle	Nome	54 10 N	150 45 W	Oct. 28	Noon, 28	Oct. 31	28.94	E	SE, 9	SSW	SE, 9	SE-SSE.
Toba Maru, Jap. S. S.	Yokohama	San Francisco	45 00 N	145 00 W	Oct. 30	8 a., 31	do	29.47	WSW	W, —	WNW	W, 8	2 pts.
Melville Dollar, Am. S. S.	Everett	Shanghai	41 27 N	154 31 W	do	Noon, 30	do	29.49	W	W, 7	NW	—, 9	4 pts.
SOUTH PACIFIC OCEAN													
Tymeric, Br. S. S.	Newcastle	Corral, Chile	36 40 S	98 00 W	Oct. 3	Noon, 3	Oct. 4	29.40	N	NW, 8	W	N, 9	N-NW-W.
SOUTH ATLANTIC OCEAN													
Eskdalegate, Br. S. S.	River Tyne	Buenos Aires	29 49 S	48 00 W	Oct. 14	4 p., 14	Oct. 15	[2]29.96	SW	W, 9	W	W, 9	WSW-W.

[1] Vessel's position approximate.

[2] Barometer readings uncorrected.

NORTH PACIFIC OCEAN

By Willis E. Hurd

Atmospheric pressure.—An inspection of Table 1 shows that the coastal section of the United States had practically normal atmospheric pressure for October, 1931, while the entire Aleutian region and Alaskan waters had pressure considerably below the normal for the month. It was here also somewhat lower than the normal even for midwinter. A decided downward trend of the barometer in northern waters began about the 10th, and thereafter until the end of the month a succession of deep lows crossed the upper steamship routes, the Bering Sea, and the Gulf of Alaska. The average center of the Aleutian low in October lay in the neighborhood of Kodiak, where the pressure for the month was 29.41 inches.

The North Pacific high lay as usual off the California coast fluctuating somewhat, as lows pressed upon or penetrated into it, but maintaining its existence fairly intact throughout the month.

In Asiatic waters a succession of lows and typhoons rendered pressure conditions as usual very unstable.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, October, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrows [1] [2]	29.80	−0.13	30.30	27th [4]	29.34	17th.
Dutch Harbor [1] [3]	29.57	−0.08	30.18	1st [4]	28.52	16th.
St. Paul [1]	29.51	−0.12	30.14	18th	28.58	13th.
Kodiak [1]	29.41	−0.18	29.94	5th	28.60	21st.
Midway Island [1]	30.08	+0.05	30.22	18th	29.88	5th.
Honolulu [5]	29.99	−0.01	30.09	20th	29.84	10th.
Juneau [5]	29.75	−0.12	30.49	6th	28.90	31st.
Tatoosh Island [5] [6]	30.01	0.00	30.44	7th	29.14	21st.
San Francisco [5] [6]	30.02	+0.01	30.26	26th	29.66	18th.
San Diego [5] [6]	29.96	+0.01	30.09	15th	29.73	18th.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] For 30 days.
[4] And on other dates.
[5] A. m. and p. m. observations.
[6] Corrected to 24-hour mean.

Cyclones and gales.—Storminess on the North Pacific did not assume severe proportions as a rule until after the 10th of October. Prior to that date two typhoons originated in the Far East, and moderate cyclonic conditions prevailed over the northern waters, causing gales of force 8 to 9 over scattered areas from the central Aleutians eastward.

On the 11th the Aleutian cyclone spread out and deepened, with the result that local gales of force as high as 10 occurred near the Peninsula of Alaska, and of lesser force over a considerable surrounding region. On the 15th the most vigorous extratropical cyclone of the month lay over and to the southward of the western Aleutians. Since a typhoon was moving rapidly eastward from a position southeast of the Kuril Islands on the 14th its influence was in all probability a great factor in increasing the energy of the Aleutian cyclone central west of the one hundred and eightieth meridian, between 40° and 50° latitude, on the 15th. On this date the maximum reported strength of the gales had risen to force 11 near 47° N., 175° E., and pressure had fallen below 28.50 inches south of Atka, Aleutian Islands. On the 16th a radio report from the American steamship *Grays Harbor*, near 50° N., 175° W., indicated that the vessel was experiencing a northwest wind of hurricane velocity. The storm moved northeastward with diminshing intensity and by the 19th had largely entered the continent through Alaska.

This cyclone was quickly succeeded by another Aleutian storm which moved into south Alaskan waters and there remained from the 20th to 24th, with central pressures below 28.50 inches on the first two days and moderate to whole gales blowing north of the fiftieth parallel. Thenceforth to the end of October pulsations of the Aleutian low covered the Gulf of Alaska, accompanied by scattered gales of moderate to strong force, that were experienced from the 27th to 31st as far south as the fortieth parallel.

Moderate to fresh gales were reported off the central California coast on the 8th and 17th, associated with the activities at the rear of lows then central over Nevada. Another California coast gale was that of the 21st, on which date the Gulf of Alaska low extended almost to the latitude of San Francisco.

Over the western part of the North Pacific Ocean, between the Asiatic coast and 160° east longitude, such stormy weather as prevailed resulted from the continental cyclones that went seaward from northern Japan and Siberia, and from such tropical depressions and typhoons as occurred.

From the few reports of our marine observers, in lower Asiatic waters, in conjunction with the Tokyo Weather maps, the tracks of four October typhoons can be plotted. All originated in low latitudes between the Caroline and Philippine Islands, and two moved westward over or near Luzon into the China Sea. These two were the typhoons of October 6 to 11 and October 15 to 20. Little is known at this writing as to the actual violence of these storms, except that the earlier developed hurricane force on the 10th some 300 to 350 miles south of Hong Kong, as shown in the report of the British tanker *Achilles*. This vessel also during a period of five minutes beginning at 8.30 a. m., passed through the typhoon's region of central calm.

The two other typhoons, one of the 6th to 14th, and the other of the 20th to 27th, passed well into middle latitudes. The earlier recurved near 22° N., 127° E., crossed the Nansei Islands on the 12th and central Japan on the 13th, and with increased velocity of progression went seaward where it seems to have become a part of the prevalent Aleutian low. Thirty lives were reported lost in Japan as this storm passed. Fresh to strong gales attended its passage over the ocean on the 14th, after leaving Japan. The other typhoon did not go so far to the westward. It recurved toward northeast on the 24th near the twentieth parallel, near 133° east longitude, crossed the Ogasawara Islands on the 25th, and was last identified on the 27th near 42° N., 155° E.

No tropical cyclones occurred in Mexican west coast waters this month. And no northers of moment occurred in the Gulf of Tehuantepec until the 31st, when a moderate northwest gale was experienced there during the southward movement of a strong anticyclone over the United States.

Winds at Honolulu.—The prevailing wind direction at Honolulu was from the east, and the maximum velocity was 24 miles an hour from the northeast on the 21st.

Fog.—The production of fog lessened materially along the trans-Pacific routes, and thick weather from this source was of little moment even in northern waters.

Fog was general, however, for some distance east of the Kuril Islands on the 1st to 4th. It was only along the American coast that fog formed readily and frequently this month. Here between North Head and Point Arguello it formed on at least 12 to 15 days of the month. Off the west coast of Lower California it was reported on 7 days.

First nonstop flight across the Pacific.—On October 3 at 5.01 p. m. (E. S. T.) Clyde Pangborn and Hugh Herndon, American flyers, took off in a plane from Samoshiro Beach, near Tokyo, Japan, and landed at Wenatchee, Wash., at 10.14 a. m. (E. S. T.) on October 5, after a flight of 41 hours and 13 minutes, covering a distance of 4,877 miles.

The start was made under good weather conditions, with an anticyclone overlying Japan on the 3d. Southeast of the Kuril Islands, on the 3d and 4th, some fog seems to have been the only hazard confronting the early part of the trip. The Aleutian LOW was comparatively shallow and not stormy, but rather, seems to have given favoring winds over much of the north-central part of the ocean. Fine anticyclonic weather prevailed for a long distance westward from the American coast on the 5th. The weather hardly could have been more favorable for such a trip in October.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

Table 1 shows the average temperatures for the Caribbean Sea and the Straits of Florida for October of each year from 1919 to 1930, inclusive, and Table 2 summarizes the temperatures for October, 1930, in the same areas. The chart shows the number of observations taken in October, 1930, within each 1-degree square and mean temperature data for subdivisions of the area considered.

The surface waters of the Caribbean average nearly as warm in October as in the warmest month of the year, September. From a mean temperature at, or near, the yearly maximum, the water cools at a rate somewhat more pronounced than is the rise in its temperature during September, but still at so slow a rate that, throughout the month, the sea retains the high surface temperature characteristic of the summer season.

Autumn conditions, however, are in evidence in the region of the Florida Straits. The temperature drops with comparative rapidity, usually approaching, by the end of October, the yearly mean for the area, while throughout the month the straits are cooler than the Caribbean, a winter characteristic.

October, 1930, was cooler than the 11-year October mean in the straits, and warmer than the mean in the Caribbean for the eighth consecutive month of 1930, with all four quarters of the month warmer than the 11-year mean for either September or October.

TABLE 1.—*Mean sea-surface temperatures in the Caribbean Sea and the straits of Florida for October, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean (° F.)	Number of observations	Mean (° F.)
1919 [1]	92	82.2	29	81.8
1920	132	82.0	39	79.9
1921	252	82.1	74	82.0
1922	248	82.4	90	81.6
1923	290	81.6	108	81.1
1924	286	82.6	112	80.6
1925	389	82.5	121	82.8
1926	453	83.0	180	82.0
1927	558	83.4	179	81.8
1928	550	82.6	160	82.3
1929	623	82.5	201	80.1
1930	627	82.9	177	81.2
Mean (1920–1930)		82.5		81.4

[1] Not used in computations because of insufficient data available.

TABLE 2.—*Mean sea-surface temperatures (°F.), and number of observations, October, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	Oct. 1-7	152	82.8			41	82.2		
II	Oct. 8-15	172	82.8			43	81.5		
III	Oct. 16-23	148	83.1			49	81.3		
IV	Oct. 24-31	155	82.8			44	79.6		
Month		627	82.9	+0.4	−0.1	177	81.2	−0.2	−2.3

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, October, 1931

[For description of tables and charts, see REVIEW, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	68.3	+3.8	Decatur	97	5	Valley Head	30	31	1.73	−0.94	Robertsdale	7.59	Milltown	T.
Arizona	63.5	+0.8	Gila Bend	104	6	Fort Valley	13	31	0.64	−0.17	Henrys Camp	2.50	6 stations	0.00
Arkansas	67.1	+4.7	Dumas	98	10	2 stations	26	31	2.35	−0.82	Gravette	10.22	Wynne	0.65
California	59.4	−0.4	2 stations	102	[1] 5	Twin Lakes	5	26	1.26	+0.04	Camptonville	7.73	26 stations	0.00
Colorado	49.6	+3.0	Las Animas	98	21	Dillon	−7	30	1.00	−0.36	Pagosa Springs	2.98	2 stations	0.00
Florida	74.5	+1.5	Tarpon Springs	95	6	Vernon	35	31	2.41	−1.86	Fort Lauderdale	12.38	Fernandina	0.10
Georgia	67.6	+2.7	2 stations	95	[1] 6	Blairsville	24	20	1.04	−1.69	Moultrie	3.70	Glennville	T.
Idaho	47.8	+0.9	3 stations	89	1	Mud Lake	12	27	1.43	−0.04	Falls Ranger Station	3.68	Challis	0.00
Illinois	59.6	+4.3	2 stations	91	5	Mount Carroll	28	18	3.71	+0.96	Casey	8.37	New Burnside	1.47
Indiana	58.6	+4.0	Scottsburg	90	3	Delphi	25	18	3.72	+0.98	Greencastle	6.72	Vevay (near)	1.80
Iowa	56.8	+5.0	2 stations	92	10	2 stations	28	[1] 17	3.01	+0.58	Bedford	6.67	Allison	0.62
Kansas	61.7	+4.8	Ashland	99	6	2 stations	10	31	1.60	−0.52	Hanover	3.70	Jetmore	0.26
Kentucky	62.0	+3.8	Lovelaceville	93	5	Farmers	28	19	3.01	+0.24	Bardstown	5.77	Pikeville	1.32
Louisiana	72.4	+4.3	3 stations	98	[1] 9	St. Joseph	29	31	3.31	−0.01	Burrwood	13.44	Grand Coteau	0.88
Maryland-Delaware	59.3	+2.9	Stevensville, Md	91	8	Oakland, Md	22	[1] 19	1.78	−1.10	Easton, Md	4.08	Cumberland, Md	0.71
Michigan	53.4	+4.4	Morenci	92	6	2 stations	19	12	3.07	+0.36	Wellston	6.38	Caro	0.72
Minnesota	51.3	+5.6	Beardsley	90	2	Meadowlands	18	12	2.48	+0.63	Pigeon River Bridge	5.72	Milan	0.75
Mississippi	69.5	+4.2	Columbia	98	5	2 stations	31	19	1.82	−0.75	Bay St. Louis	4.82	Vicksburg	0.88
Missouri	61.7	+4.3	2 stations	95	5	Dean	27	31	3.45	+0.56	Dean	6.82	Arcadia	0.99
Montana	46.1	+1.6	do	88	[1] 2	Ingomar (near)	7	30	0.42	−0.63	Crow Agency	2.29	5 stations	0.00
Nebraska	55.6	+4.5	do	93	[1] 4	Gordon	-1	31	1.19	−0.41	Falls City	4.60	2 stations	0.23
Nevada	54.3	+2.8	Logandale	96	[1] 4	Zorra Vista Ranch	14	12	0.39	−0.23	Sharp	1.49	Lovelock	0.00
New England	52.6	+3.1	3 stations	86	[1] 18	Hoosac Tunnel, Mass.	18	19	3.29	−0.24	Danforth, Me	7.94	Westfield, Mass	1.44
New Jersey	58.3	+3.4	Canoe Brook	92	8	Layton	24	13	2.76	−0.99	Bayonne	4.69	Culvers Lake	1.67
New Mexico	55.8	+2.3	Carlsbad	95	[1] 6	Elizabethtown	8	30	0.97	−0.25	Carrizozo	4.02	6 stations	0.00
New York	53.2	+3.3	4 stations	86	[1] 3	3 stations	22	[1] 10	2.44	−0.89	High Market	.5.48	Dansville	0.73
North Carolina	61.9	+2.0	Southern Pines	96	7	Mount Mitchell	19	31	1.11	−2.23	Brevard	4.26	Willard	0.26
North Dakota	47.7	+4.2	Wahpeton	90	2	Washburn	10	29	1.39	+0.35	Sharon	3.94	Howard	T.
Ohio	57.3	+3.4	5 stations	89	[1] 4	3 stations	25	[1] 18	2.42	−0.29	Franklin	4.80	Cadiz	1.03
Oklahoma	67.3	+5.6	Hollis	103	6	2 stations	19	31	4.43	+1.24	Tahlequah	11.07	Buffalo	0.54
Oregon	49.1	+0.4	Pendleton	93	1	Seneca	−1	12	2.49	+0.48	Crossett	10.08	Kingman	0.06
Pennsylvania	55.7	+3.3	Holtwood	93	7	Ridgway	20	[1] 13	1.83	−1.43	Hamburg	4.30	Wellsboro	0.20
South Carolina	65.9	+2.3	Garnett	98	11	Santuck	28	19	0.80	−2.17	Caesars Head	3.06	2 stations	T.
South Dakota	52.3	+4.0	2 stations	89	[1] 2	Oelrichs	7	31	1.32	−0.06	Webster	3.08	Pollock	0.11
Tennessee	64.2	+4.8	Carthage	96	6	Erwin	22	18	1.88	−0.96	Spencer	3.30	Embreeville	0.68
Texas	72.8	+5.2	Fort Stockton	105	6	Spearman	21	31	2.26	−0.50	Abilene	10.21	4 stations	0.00
Utah	52.1	+2.9	St. George	91	[1] 9	Soldiers Summit	7	27	0.82	−0.50	Monticello	2.43	2 stations	T.
Virginia	60.3	+2.8	Kenbridge	93	6	Burkes Garden	18	19	1.10	−1.89	Christchurch	4.17	Wallaceton	0.09
Washington	49.1	−0.1	2 stations	90	1	Chewelah	16	21	3.64	+0.64	Wynoochee Oxbow	15.27	Sixprong (near)	0.05
West Virginia	57.0	+2.7	Wardensville	98	7	Marlinton	18	19	1.66	−1.47	Terra Alta	3.03	Union	0.58
Wisconsin	52.9	+4.9	2 stations	85	[1] 3	Solon Springs	17	12	3.03	+0.68	West Bend	5.05	Prairie du Chien	1.26
Wyoming	45.1	+2.0	Pinebluff	84	2	Pinedale	6	27	1.31	+0.03	Bechler River	4.55	Powell	0.18
Alaska (Sept.)	43.9	−0.4	Haines	75	7	Barrow	10	[1] 20	3.46	−0.49	Mt. Roberts (h)	22.09	Barrow	0.12
Hawaii	74.8	+1.0	2 stations	94	[1] 10	Kanalohuluhulu	46	31	6.69	+1.21	Kukaua	20.89	Kalae	0.00
Porto Rico	79.1	+0.5	Mayaguez	97	[1] 14	Guineo	53	17	8.43	+0.22	La Fo	20.39	Santa Rita	1.55

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1931*

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							54.8	+3.7										76	3.26	0.0										4.8		
Eastport	76	67	85	29.86	29.94	−0.06	50.1	+2.6	73	8	56	34	13	44	27	47	44	82	4.72	+1.2	12	7,212	nw.	40	se.	16	8	5	18	6.7	0.0	0.0
Greenville, Me	1,070	6	----	28.79	29.96	------	47.5	------	79	4	57	27	10	38	33	----	----	----	3.87	------	14	5,162	se.	28	------	26	10	7	14	----	T.	0.0
Portland, Me	103	82	117	29.85	29.98	−.06	53.8	+3.9	79	8	62	33	19	46	26	47	42	72	4.35	+1.2	9	5,662	w.	32	nw.	26	15	7	9	4.3	0.0	0.0
Concord	289	70	79	29.69	30.01	−.04	51.6	+1.9	84	4	63	29	11	40	40	----	----	----	3.45	+0.6	9	3,386	nw.	21	nw.	27	15	4	12	4.8	0.0	0.0
Burlington	403	11	48	29.56	30.00	−.04	51.6	+2.4	79	4	60	29	10	43	32	----	----	----	2.52	−0.4	12	6,472	s.	37	s.	11	9	7	15	6.2	0.0	0.0
Northfield	876	12	60	------	30.02	−.02	48.6	+3.1	80	4	60	23	10	37	41	----	----	82	2.28	−0.6	14	4,339	s.	25	s.	11	9	9	13	5.9	0.0	0.0
Boston	125	106	165	29.86	30.00	−.05	58.5	+4.9	84	5	67	40	19	50	26	51	45	69	2.18	−1.0	7	5,055	nw.	27	nw.	27	15	9	7	4.1	0.0	0.0
Nantucket	12	14	90	29.99	30.00	−.05	57.7	+3.5	76	6	64	42	19	52	19	53	50	80	5.57	+2.2	9	10,023	sw.	36	sw.	17	12	8	11	5.1	0.0	0.0
Block Island	26	11	46	29.98	30.01	−.04	58.0	+3.1	76	6	63	43	18	53	18	53	50	78	4.41	+0.8	8	10,342	w.	46	nw.	26	18	8	5	3.9	0.0	0.0
Providence	160	215	251	29.83	30.00	−.05	57.4	+5.2	82	8	67	35	19	48	27	51	46	72	2.40	−0.7	9	7,205	nw.	42	nw.	25	17	9	5	3.5	0.0	0.0
Hartford	159	122	----	29.84	30.01	−.05	57.5	+6.3	83	3	68	37	13	48	34	----	----	----	1.75	−1.8	9	------	sw.	----	------	----	14	10	7	4.2	0.0	0.0
New Haven	106	74	153	29.92	30.03	−.03	58.1	+4.3	83	8	68	38	19	49	29	51	47	73	2.23	−1.4	8	4,987	sw.	27	nw.	26	15	11	5	3.8	0.0	0.0
Middle Atlantic States							60.0	+3.4										73	1.61	−1.4										4.5		
Albany	97	107	115	29.92	30.03	−.03	55.0	+2.9	82	5	64	34	10	45	31	48	44	75	1.37	−1.4	10	3,742	s.	20	nw.	26	15	4	12	4.6	0.0	0.0
Binghamton	871	10	84	29.13	30.07	+.01	53.3	+3.3	81	5	65	28	13	42	39	----	----	----	1.02	−2.0	10	3,154	e.	21	nw.	26	10	3	18	6.0	0.0	0.0
New York	314	414	454	29.70	30.04	−.02	60.4	+4.1	85	6	68	41	19	52	25	53	48	70	2.87	−0.7	11	9,474	nw.	50	nw.	26	11	12	8	5.1	0.0	0.0
Bellefonte	1,050	5	36	28.96	30.08	------	53.0	------	82	4	66	25	20	40	45	47	43	79	1.04	------	8	------	w.	36	w.	16	7	10	14	6.0	0.0	0.0
Harrisburg	374	94	104	29.67	30.07	−.01	58.9	+4.1	84	6	69	37	13	49	32	51	45	68	2.13	−0.8	8	3,576	w.	26	nw.	25	13	10	8	4.5	0.0	0.0
Philadelphia	114	123	367	29.95	30.08	+.01	62.6	+4.8	85	6	71	45	19	54	24	54	48	66	2.61	−0.2	8	7,802	sw.	34	n.	12	12	10	9	4.6	0.0	0.0
Reading	325	81	103	29.72	30.07	------	58.8	+4.1	85	4	69	37	13	49	29	52	49	76	2.06	−1.1	7	2,983	sw.	22	w.	25	13	10	8	4.7	0.0	0.0
Scranton	805	72	103	29.22	30.08	+.01	54.9	+3.0	83	4	66	30	13	44	37	48	45	77	1.45	−1.6	10	3,565	n.	33	nw.	25	10	11	10	5.0	0.0	0.0
Atlantic City	52	37	172	30.00	30.06	−.01	61.5	+4.6	80	6	69	40	19	54	26	55	52	75	2.11	−1.1	8	9,542	w.	40	w.	25	10	8	7	3.9	0.0	0.0
Cape May	17	13	49	------	------	------	61.6	+2.0	82	3	69	40	19	54	25	57	53	78	1.94	−1.4	7	------	nw.	----	------	----	12	11	8	----	0.0	0.0
Sandy Hook	22	10	55	30.02	30.04	------	60.6	------	82	6	67	44	19	54	22	54	51	76	2.41	−1.4	11	8,823	w.	38	n.	25	13	11	7	4.2	0.0	0.0
Trenton	190	159	183	29.86	30.06	------	59.6	+4.0	86	6	70	37	19	49	28	52	47	72	2.22	−0.6	10	5,770	w.	31	nw.	26	13	10	8	4.4	0.0	0.0
Baltimore	123	100	215	29.94	30.07	−.01	63.4	+5.2	88	8	73	44	18	54	30	54	48	64	1.79	−1.1	4	5,605	sw.	32	sw.	25	13	10	8	4.3	0.0	0.0
Washington	112	62	85	29.96	30.08	.00	61.2	+3.8	88	6	72	37	19	50	38	53	48	72	1.28	−1.6	7	3,017	sw.	24	nw.	17	16	10	5	4.1	0.0	0.0
Cape Henry	18	8	54	30.07	30.09	------	64.8	+2.7	88	7	73	45	20	57	25	58	54	74	0.57	−2.4	4	7,436	sw.	45	n.	26	14	14	3	3.8	0.0	0.0
Lynchburg	681	153	188	29.37	30.12	+.03	61.0	+2.5	87	7	74	34	19	48	44	52	47	71	0.67	−2.5	6	2,992	nw.	20	w.	25	18	7	6	4.0	0.0	0.0
Norfolk	91	170	205	30.01	30.11	+.04	65.2	+2.7	88	6	74	47	20	57	24	57	52	70	0.74	−2.3	3	7,097	s.	29	nw.	17	17	10	4	3.7	0.0	0.0
Richmond	144	11	52	29.96	30.11	+.03	62.3	+2.7	88	7	75	36	19	50	36	55	52	80	1.15	−1.7	7	3,980	sw.	26	sw.	28	15	11	5	3.5	0.0	0.0
Wytheville	2,304	49	55	27.76	30.14	+.05	55.6	+2.0	81	5	08	26	19	43	43	48	43	73	0.62	−2.2	4	3,502	w.	22	sw.	25	14	7	10	4.3	0.0	0.0
South Atlantic States							67.1	+2.8										71	0.78	−2.5										3.4		
Asheville	2,253	89	104	27.81	30.16	+.07	58.8	+3.5	84	5	72	30	19	45	44	49	44	71	0.49	−2.3	5	3,729	nw.	22	nw.	25	18	8	5	4.0	0.0	0.0
Charlotte	779	55	62	29.30	30.13	+.05	65.0	+3.3	90	6	77	39	19	54	34	54	48	64	1.26	−1.7	4	2,292	sw.	16	w.	15	18	8	5	3.2	0.0	0.0
Greensboro	886	5	56	29.18	30.14	------	60.4	------	89	6	75	28	18	46	46	51	48	76	0.45	------	5	4,039	sw.	25	nw.	15	18	7	6	3.5	0.0	0.0
Hatteras	11	5	50	30.08	30.10	+.04	67.2	+1.3	84	5	74	50	21	60	23	64	63	89	0.64	−4.3	4	6,905	ne.	30	ne.	12	18	9	4	3.1	0.0	0.0
Raleigh	376	103	146	29.72	30.12	+.05	64.6	+2.6	88	6	76	41	19	54	32	55	49	64	0.80	−2.1	3	4,805	sw.	25	nw.	15	19	7	5	3.2	0.0	0.0
Wilmington	78	81	91	30.05	30.13	+.07	67.0	+1.7	85	5	78	44	19	56	33	59	55	75	0.50	−2.8	2	3,494	n.	24	sw.	29	21	7	3	2.7	0.0	0.0
Charleston	48	11	92	30.06	30.11	+.05	70.2	+2.4	85	25	78	48	31	62	26	63	60	76	0.71	−2.6	4	6,397	ne.	27	ne.	18	18	8	5	3.4	0.0	0.0
Columbia, S. C	351	41	57	29.75	30.13	+.06	67.5	+3.2	89	6	80	42	19	55	38	56	49	60	0.53	−2.0	2	3,714	ne.	26	sw.	28	22	7	2	2.4	0.0	0.0
Due West	711	10	55	29.39	30.17	------	65.2	------	88	6	78	38	31	53	38	----	----	----	1.45	------	3	4,626	w.	30	ne.	9	17	9	5	3.6	0.0	0.0
Greenville, S. C	1,039	139	146	29.03	30.13	------	65.8	+5.6	87	6	76	39	31	56	30	54	46	58	1.06	−2.1	6	4,404	ne.	28	w.	25	18	10	3	3.0	0.0	0.0
Augusta	182	62	77	29.91	30.10	+.03	68.3	+3.0	90	12	82	40	20	55	42	58	53	70	0.40	−2.1	2	2,721	nw.	19	sw.	28	21	5	5	2.8	0.0	0.0
Savannah	65	150	194	30.03	30.10	+.05	70.6	+2.7	87	25	80	46	31	61	29	62	59	77	0.34	−2.6	4	6,840	e.	26	w.	29	16	8	7	4.1	0.0	0.0
Jacksonville	43	209	245	30.03	30.08	+.06	72.9	+1.8	84	9	80	48	31	66	24	65	62	75	1.86	−2.6	6	7,578	ne.	27	n.	13	8	16	7	5.2	0.0	0.0
Florida Peninsula							77.7	+0.9										79	4.74	−1.1										5.7		
Key West	22	10	64	29.95	29.97	+.03	79.1	0.0	87	6	84	66	31	74	15	74	72	82	8.02	+2.0	17	6,752	ne.	27	s.	17	12	9	10	4.9	0.0	0.0
Miami	25	124	168	29.98	30.00	+.03	78.2	+1.2	88	16	83	61	31	74	17	72	69	76	5.66	−2.8	14	7,415	ne.	38	ne.	19	6	11	14	6.5	0.0	0.0
Tampa	35	79	197	30.00	30.04	+.06	75.8	+1.5	90	7	84	56	31	68	21	68	65	78	0.54	−2.6	7	7,050	e.	33	e.	19	9	14	8	5.2	0.0	0.0
Titusville	44	5	----	30.00	30.05	------	75.9	------	90	3	83	54	31	69	24	----	----	----	2.98	------	14	------	ne.	----	------	----	5	17	9	6.1	0.0	0.0
East Gulf States							69.9	+3.5										71	1.99	−0.9										3.6		
Atlanta	1,173	190	198	28.90	30.13	+.06	66.0	+3.0	86	12	75	40	31	57	26	55	47	59	1.05	−1.5	3	5,444	e.	25	w.	29	17	9	5	3.3	0.0	0.0
Macon	370	78	87	29.73	30.12	+.06	66.5	+2.0	88	6	79	41	20	54	38	56	51	67	1.42	−0.9	3	3,379	ne.	19	sw.	28	19	5	7	3.2	0.0	0.0
Thomasville	273	49	103	29.79	30.09	+.05	71.3	+3.1	89	6	82	43	31	61	30	62	57	71	0.89	−2.1	2	4,435	ne.	17	ne.	2	15	10	0	4.2	0.0	0.0
Apalachicola	36	11	51	30.03	30.07	------	73.0	------	90	15	80	48	31	66	23	66	64	77	0.15	−3.0	2	5,734	e.	24	e.	1	16	8	7	3.7	0.0	0.0
Pensacola	56	149	185	30.02	30.08	+.05	72.4	+2.5	88	10	78	44	31	66	18	65	62	74	5.83	+1.6	4	8,050	e.	47	sw.	7	16	11	4	3.4	0.0	0.0
Anniston	741	9	57	------	------	------	65.6	+3.2	89	6	79	37	30	52	43	----	----	----	0.46	−2.2	2	2,599	se.	18	w.	29	16	9	6	----	0.0	0.0
Birmingham	700	11	48	29.36	30.12	+.05	69.4	+4.6	92	5	80	41	30	58	28	58	52	65	2.05	−0.4	3	3,683	se.	17	sw.	28	10	13	2	3.0	0.0	0.0
Mobile	57	125	161	30.02	30.08	+.04	72.6	+3.3	89	10	81	45	31	64	26	65	62	77	3.58	0.0	7	5,290	e.	22	se.	4	16	11	4	3.7	0.0	0.0
Montgomery	223	100	112	29.87	30.12	+.06	70.0	+3.4	89	12	80	44	31	60	34	59	53	65	0.88	−1.6	3	3,052	e.	20	e.	1	18	8	5	3.2	0.0	0.0
Corinth	469	6	----	------	------	------	68.2	------	93	6	82	36	19	54	44	----	----	----	1.28	------	2	------	se.	----	------	----	11	19	1	----	0.0	0.0
Meridian	375	87	95	29.70	30.09	+.03	68.8	+4.5	89	10	80	40	31	58	35	60	57	75	1.37	−1.0	4	2,491	se.	17	w.	29	16	8	7	4.0	0.0	0.0
Vicksburg	247	05	73	29.82	30.10	+.04	71.4	+4.7	92	10	81	40	31	62	30	62	57	71	0.88	−1.9	7	4,000	se.	20	w.	29	15	10	6	3.6	0.0	0.0
New Orleans	53	76	84	30.01	30.06	+.03	75.2	+4.2	88	11	81	52	31	69	19	67	64	78	5.36	+2.1	9	3,914	e.	17	e.	1	17	6	8	4.2	0.0	0.0
West Gulf States							73.8	+5.9										72	2.47	−0.6										3.7		
Shreveport	249	204	220	29.80	30.06	+.01	72.3	+5.7	94	9	82	41	31	62	30	62	57	67	2.66	0.0	4	5,638	s.	29	n.	28	22	7	2	2.8	0.0	0.0
Bentonville	1,303	11	44	28.69	30.04	−.01	64.3	+6.3	90	4	75	32	31	54	32	----	----	----	8.36	------	9	2,388	s.	16	nw.	29	21	5	5	5.2	0.0	0.0
Fort Smith	457	79	94	29.57	30.04	−.01	68.4	+5.6	93	10	79	36	31	58	28	60	55	70	6.32	+3.3	8	4,488	c.	34	nw.	29	15	12	4	4.1	0.0	0.0
Little Rock	357	136	153	29.70	30.08	+.02	68.2	+4.6	91	10	78	40	31	58	30	59	54	70	1.76	−1.0	6	4,489	s.	31	w.	29	12	12	7	4.0	0.0	0.0
Austin	605	136	148	29.39	30.02	------	77.0	+8.7	95	7	88	43	31	66	30	65	60	66	0.15	−3.0	3	4,495	se.	25	ne.	15	13	16	2	3.9	0.0	0.0
Brownsville	57	83	100	29.93	29.99	------	79.2	+4.3	94	6	88	60	31	71	22	71	69	80	4.47	+1.2	9	5,482	se.	21	e.	9	15	12	4	4.0	0.0	0.0
Corpus Christi	20	11	78	29.99	30.01	+.01	79.0	+5.8	90	28	84	63	30	74	19	72	69	77	0.34	−2.1	5	7,083	se.	27	ne.	1	17	12	2	3.9	0.0	0.0
Dallas	512	220	227	29.49	30.04	------	71.7	------	92	9	81	42	31	62	27	----	----	----	2.26	−0.4	8	7,150	se.	31	ne.	15	19	6	6	3.3	0.0	0.0
Fort Worth	670	106	114	29.31	30.02	−.01	72.7	+6.0	95	7	82	42	31	63	28	62	57	68	3.39	+0.6	8	4,990	se.	22	nw.	29	18	0	7	4.0	0.0	0.0
Galveston	54	106	114	30.00	30.06	+.03	76.6	+3.9	85	5	81	57	31	72	21	70	66	75	3.40	−1.0	7	6,926	se.	25	se.	23	17	11	3	3.3	0.0	0.0
Houston	138	292	314	29.90	30.04	------	75.6	+5.3	93	7	84	50	31	67	24	----	----	----	1.09	−2.6	4	7,791	se.	29	se.	15	13	17	1	3.8	0.0	0.0
Palestine	510	64	72	29.53	30.06	+.03	73.0	+5.8	93	9	83	44	31	63	30	63	58	69	2.81	−0.5	4	4,270	s.	18	nw.	23	10	12	3	3.3	0.0	0.0
Port Arthur	34	58	66	30.00	30.04	------	75.6	------	90	8	83	47	31	68	24	68	66	80	5.14	+1.8	7	4,391	e.	21	n.	15	13	16	2	3.8	0.0	0.0
San Antonio	693	242	301	29.29	29.99	−.02	78.0	+7.5	96	7	88	51	31	68	25	67	62	66	0.75	−1.5	5	7,185	e.	32	se.	11	12	18	1	3.8	0.0	0.0
Taylor	571	38	51	29.47	30.06	+.04	75.6	+7.3	95	7	87	41	31	64	31	----	----	----	0.28	−2.8	2	4,719	s.	21	n.	15	17	13	1	3.1	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	°F. 61.0	°F. +3.3	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 72	In. 2.59	In. −0.1		Miles								0–10 5.0	In.	In.
hattanooga	762	190	215	29.30	30.12	+0.03	65.4	+3.5	87	6	76	42	19	55	35	54	47	60	1.73	−1.3	3	3,671	se.	20	sw.	29	16	12	3	3.5	0.0	0.0
noxville	995	102	111	29.08	30.14	+.05	63.2	+3.3	89	6	75	37	18	52	39	53	48	67	1.42	−1.2	2	2,991	ne.	18	sw.	29	15	10	6	4.0	0.0	0.0
lemphis	399	76	97	29.67	30.09	+.02	69.0	+5.7	90	11	79	38	31	59	30	59	53	66	0.79	−1.9	4	4,412	se.	23	sw.	27	14	12	5	4.1	0.0	0.0
lashville	546	168	191	29.54	30.13	+.05	65.2	+4.2	89	5	77	39	19	54	37	56	50	66	1.86	−0.6	7	4,928	s.	28	nw.	27	15	9	7	4.2	T.	T.
exington	989	193	230	29.07	30.14	+.06	60.8	+3.4	84	3	69	37	18	52	27	----	----	----	4.44	+1.8	12	8,137	sw.	29	sw.	27	17	3	11	4.0	0.0	0.0
ouisville	525	188	234	29.53	30.12	+.04	61.6	+2.3	86	3	71	39	19	52	31	53	48	70	2.36	−0.3	10	5,928	s.	32	sw.	27	11	9	11	5.2	0.0	0.0
vansville	431	76	116	29.63	30.10	+.02	63.4	+4.0	85	4	73	40	18	54	31	55	50	71	1.83	−1.0	9	5,202	s.	40	sw.	27	13	7	11	4.9	0.0	0.0
ndianapolis	822	194	230	29.20	30.09	+.02	59.4	+3.7	84	5	68	39	18	51	26	52	46	69	3.75	+1.0	12	6,770	s.	38	nw.	7	8	11	12	5.9	0.0	0.0
oyal Center	736	11	55	29.26	30.07	------	57.2	------	85	5	67	31	18	47	29	----	----	----	3.05	+0.1	13	5,754	sw.	25	s.	27	8	8	15	5.8	0.0	0.0
erre Haute	575	96	129	29.46	30.08	------	60.2	------	84	3	68	38	18	51	30	52	48	72	6.48	+3.8	12	5,651	s.	28	sw.	7	10	8	13	5.5	0.0	0.0
incinnati	627	11	51	29.43	30.11	+.03	59.4	+3.7	84	4	70	34	19	49	36	52	48	75	1.89	−0.6	9	3,868	sw.	19	sw.	27	12	10	9	5.0	0.0	0.0
olumbus	822	216	230	29.22	30.10	+.02	58.2	+3.0	82	4	68	35	18	49	29	51	47	73	2.41	0.0	13	6,272	s.	31	w.	16	12	9	10	5.1	0.0	0.0
ayton	899	137	173	29.14	30.10	------	58.8	+3.8	82	5	68	36	18	50	30	52	47	74	4.66	+2.1	10	4,933	sw.	28	sw.	27	11	10	10	5.4	0.0	0.0
lkins	1,947	59	67	28.10	30.17	+.07	53.8	+1.5	82	7	66	26	19	42	41	47	45	86	1.50	−1.4	13	2,684	w.	29	nw.	16	6	14	11	6.3	0.0	0.0
arkersburg	637	77	82	29.48	30.14	+.06	58.4	+2.3	86	7	69	31	19	48	36	51	48	79	2.04	−0.4	9	2,917	se.	29	nw.	16	10	7	14	5.9	0.0	0.0
ittsburgh	842	353	410	29.20	30.11	+.03	57.4	+1.7	84	7	66	37	18	48	29	50	46	74	1.21	−1.3	11	5,443	sw.	35	w.	25	9	8	14	5.7	0.0	0.0
Lower Lake Region							56.2	+4.2										72	2.18	−0.7										5.5		
uffalo	767	247	280	29.20	30.03	−.02	55.6	+3.7	77	4	62	36	17	49	29	50	45	73	1.97	−1.3	14	10,471	w.	44	sw.	11	12	9	10	5.4	0.0	0.0
anton	448	10	61	29.51	29.99	------	51.4	+4.2	79	4	61	28	9	42	35	----	----	----	2.55	−0.5	11	5,241	sw.	30	sw.	11	11	6	14	5.6	T.	0.0
haca	836	74	100	29.14	30.05	------	54.5	+3.4	83	3	65	29	13	44	39	47	42	70	0.99	−2.0	9	5,468	nw.	27	nw.	11	10	6	15	5.7	0.0	0.0
swego	335	71	85	------	30.02	−.03	55.0	+3.8	81	4	63	33	10	47	30	----	----	74	2.95	−0.3	13	6,053	s.	27	nw.	11	11	5	15	5.9	0.0	0.0
ochester	523	86	102	29.47	30.05	.00	56.0	+4.5	82	4	65	35	13	47	34	48	43	70	1.59	−1.1	11	5,244	sw.	23	sw.	5	10	9	12	5.6	0.0	0.0
yracuse	596	65	79	29.40	30.04	−.02	56.5	+5.5	84	4	65	35	18	48	30	----	----	----	1.76	−1.1	14	4,032	s.	23	nw.	25	13	5	13	5.5	0.0	0.0
rie	714	130	166	29.29	30.06	+.01	57.0	+3.6	84	4	65	38	17	50	28	50	46	74	3.53	−0.2	12	8,848	s.	30	s.	29	13	8	10	5.0	T.	0.0
leveland	762	267	337	29.24	30.06	.00	58.5	+4.9	81	4	65	41	30	52	24	51	45	65	1.76	−1.0	13	9,949	s.	50	w.	16	9	10	12	5.8	0.0	0.0
andusky	629	5	67	29.39	30.08	+.02	57.7	+3.4	85	4	66	35	18	49	29	----	----	----	2.37	−0.1	11	5,416	sw.	27	nw.	16	8	9	14	5.8	0.0	0.0
oledo	628	208	243	29.39	30.07	+.02	57.4	+4.0	83	5	66	36	18	49	28	50	46	73	1.79	−0.6	12	8,370	sw.	36	nw.	16	15	4	12	5.0	0.0	0.0
ort Wayne	856	110	119	29.14	30.07	------	57.5	+3.8	84	5	66	34	18	49	27	51	47	75	2.42	−0.2	12	5,851	sw.	28	nw.	16	13	4	14	5.5	0.0	0.0
etroit	730	218	258	29.27	30.07	+.02	57.5	+5.0	82	5	66	36	18	49	27	50	46	73	2.43	0.0	13	6,500	sw.	27	sw.	7	9	13	9	5.4	0.0	0.0
Upper Lake Region							54.0	+5.4										78	2.95	+0.2										5.8		
lpena	609	13	92	29.34	30.00	−.03	52.6	+5.5	82	3	62	31	18	44	29	48	44	79	2.96	+0.2	12	7,366	nw.	36	nw.	11	13	7	11	5.2	0.0	0.0
scanaba	612	54	60	29.31	29.98	−.03	52.2	+6.2	73	14	59	33	12	46	29	48	45	79	3.09	+0.5	13	6,949	s.	37	nw.	11	10	7	14	6.0	0.0	0.0
rand Haven	632	54	80	29.34	30.02	−.01	54.3	+3.6	76	3	62	33	18	47	31	50	47	81	2.86	−0.2	14	7,619	sw.	30	nw.	16	11	4	16	6.1	0.0	0.0
rand Rapids	707	70	244	29.26	30.04	.00	55.8	+4.6	82	3	64	35	18	48	30	49	46	76	3.18	+0.4	13	7,858	sw.	40	sw.	28	9	7	15	6.0	0.0	0.0
oughton	668	64	99	29.21	29.94	−.06	53.2	+7.5	82	2	61	35	18	46	32	----	----	----	3.02	0.0	16	6,156	w.	34	nw.	11	8	8	15	6.1	0.0	0.0
ansing	878	6	88	29.09	30.04	------	53.4	+3.1	81	4	63	30	18	44	32	49	47	86	1.80	−0.7	13	5,297	sw.	27	nw.	16	8	11	12	5.8	T.	0.0
udington	637	60	66	29.31	30.00	------	53.6	+3.9	73	3	60	35	12	48	30	50	47	81	5.64	+2.7	18	7,302	s.	33	sw.	28	13	9	9	4.9	0.0	0.0
larquette	734	77	111	29.15	29.95	−.06	53.9	+7.2	82	2	61	36	17	47	30	47	43	74	3.15	+0.4	13	8,124	s.	36	w.	24	7	6	18	6.8	T.	0.0
ort Huron	638	70	120	29.34	30.03	−.01	55.4	+4.9	80	4	64	33	18	47	29	49	46	77	1.35	−1.1	10	6,989	s.	29	nw.	17	11	9	11	5.5	0.0	0.0
ult Sainte Marie	614	11	52	29.29	29.99	−.02	50.9	+6.3	76	3	58	31	18	43	29	46	44	83	2.82	−0.9	15	5,601	se.	33	nw.	25	9	6	16	6.5	0.0	0.0
hicago	673	7	131	29.32	30.04	.00	58.8	+4.8	83	3	66	40	18	52	24	52	48	74	2.62	+0.1	11	6,965	sw.	29	ne.	11	12	8	11	5.4	0.0	0.0
reen Bay	617	109	141	29.32	29.98	−.04	53.8	+5.3	79	3	61	36	18	46	25	48	44	79	3.76	+1.2	10	7,032	s.	27	sw.	27	8	7	16	6.2	0.0	0.0
lilwaukee	681	125	221	29.28	30.01	−.02	56.7	+5.6	82	3	64	39	29	50	25	50	46	73	2.10	−0.2	10	9,018	w.	33	w.	7	10	9	12	5.5	0.0	0.0
uluth	1,133	5	47	28.71	29.93	−.07	50.9	+6.8	79	2	60	33	12	42	27	45	41	77	2.90	+0.6	14	8,235	sw.	38	nw.	10	11	7	13	5.7	0.0	0.0
North Dakota							48.4	+4.6										72	1.53	+0.3										5.0		
oorhead	940	50	58	28.92	29.95	−.05	50.5	+6.0	86	2	61	31	12	40	42	44	39	74	2.34	+0.6	8	6,173	s.	30	nw.	27	11	6	14	5.7	T.	0.0
ismarck	1,674	8	57	28.18	29.98	−.01	48.6	+3.7	82	1	60	29	11	38	38	41	37	73	1.19	+0.2	8	6,330	nw.	38	nw.	27	16	6	9	4.3	0.2	0.0
evils Lake	1,478	11	44	28.37	29.96	−.03	47.0	+4.6	82	2	57	29	12	37	34	41	37	78	2.29	+1.0	5	6,821	sw.	30	nw.	27	9	8	14	5.8	0.1	0.0
llendale	1,457	10	56	28.38	29.96	------	48.8	------	84	2	61	28	11	37	46	----	----	----	1.66	+0.5	9	9,635	nw.	43	nw.	27	12	5	14	5.5	1.0	0.0
rand Forks	833	12	67	------	------	------	48.7	------	84	1	60	27	11	38	44	42	----	----	3.65	------	9	------	nw.	39	nw.	10	9	8	14	----	0.0	0.0
illiston	1,878	41	48	28.00	29.99	+.01	47.6	+4.2	78	1	60	23	22	36	41	39	33	65	0.15	−0.7	2	5,377	w.	32	nw.	27	16	9	6	3.8	0.0	0.0
Upper Mississippi Valley							58.4	+5.3										75	2.93	+0.5										5.5		
inneapolis	918	102	208	28.96	29.94	------	54.4	+5.5	81	2	63	38	30	46	30	----	----	----	1.87	−0.2	13	7,718	se.	34	se.	26	13	4	14	5.5	0.0	0.0
. Paul	837	114	149	29.05	29.96	−.05	54.2	+5.6	80	2	63	37	25	46	29	----	----	----	2.31	+0.1	13	5,492	sw.	28	w.	27	13	5	13	5.3	0.0	0.0
ı Crosse	714	11	48	29.21	29.99	−.03	55.2	+4.9	81	3	64	33	17	47	33	50	47	83	4.18	+1.9	12	3,240	s.	18	sw.	27	14	1	16	5.7	0.0	0.0
adison	974	70	78	28.96	30.00	−.03	54.9	+4.6	80	3	62	38	29	48	27	49	45	76	3.11	+0.7	12	5,761	s.	24	sw.	27	12	5	14	5.4	T.	0.0
ausau	1,247	4	62	28.64	29.98	------	51.9	------	78	3	60	31	12	43	35	----	----	----	2.51	−0.3	12	4,269	s.	24	sw.	27	10	4	17	6.4	0.0	0.0
harles City	1,015	10	51	28.93	30.02	.00	55.0	+6.4	81	2	64	33	17	46	30	49	45	79	1.07	−1.3	8	4,625	se.	23	w.	27	15	5	11	5.1	0.0	0.0
ıvenport	606	143	118	29.37	30.03	−.01	59.0	+5.3	83	3	67	39	31	51	23	52	48	73	3.01	+0.6	15	6,553	s.	34	w.	27	10	7	14	5.8	0.0	0.0
es Moines	861	5	99	29.10	30.01	−.02	58.6	+5.2	84	10	67	37	29	50	26	52	48	76	3.54	+1.0	13	6,798	s.	32	nw.	7	11	7	13	5.6	0.0	0.0
ıbuque	700	81	96	29.26	30.02	−.02	56.8	+4.9	81	3	64	35	18	50	26	51	47	76	2.92	+0.4	11	3,899	s.	19	n.	16	12	3	16	6.0	0.0	0.0
eokuk	614	64	78	29.38	30.05	.00	60.4	+5.0	87	5	69	40	31	52	28	53	49	73	4.05	+1.8	13	4,807	sw.	29	w.	5	12	8	11	5.1	0.0	0.0
iro	358	87	93	29.70	30.08	+.01	65.0	+4.6	86	7	74	42	31	56	29	56	52	72	2.66	−0.1	8	4,636	s.	25	sw.	27	10	10	11	5.2	0.0	0.0
oria	609	11	45	29.40	30.06	+.01	59.2	+7.2	88	5	68	34	18	50	30	52	49	78	3.15	+0.9	13	3,633	s.	21	w.	28	12	7	12	5.2	0.0	0.0
ringfield, Ill.	636	5	191	29.37	30.05	.00	60.7	+4.9	88	5	70	38	18	52	28	53	49	73	3.51	+1.0	10	8,124	s.	29	se.	7	11	5	15	5.8	0.0	0.0
ınnibal	534	74	109	29.48	30.06	+.01	61.4	+5.4	88	5	70	37	18	53	27	----	----	----	3.16	+0.8	10	5,737	sw.	23	w.	28	12	5	14	5.5	0.0	0.0
. Louis	568	265	303	29.46	30.06	.00	62.9	+4.6	87	4	71	42	29	55	26	54	49	68	2.90	+0.2	10	8,299	s.	31	sw.	23	13	6	12	4.8	0.0	0.0
Missouri Valley							58.3	+4.6										69	1.87	−0.2										4.9		
ılumbia, Mo.	784	6	84	29.22	30.05	.00	62.0	+5.4	87	6	71	40	18	53	29	----	----	----	3.15	+0.5	10	4,798	s.	20	w.	29	12	9	10	5.1	0.0	0.0
ınsas City	963	161	181	29.02	30.05	+.01	62.5	+4.8	89	10	71	38	30	54	27	54	50	69	3.02	+0.1	9	6,286	s.	34	sw.	27	12	9	10	5.1	T.	0.0
. Joseph	967	11	49	28.99	30.03	------	60.8	------	90	10	70	37	17	52	28	53	49	74	1.92	−0.8	9	5,553	nw.	37	w.	26	13	10	8	4.6	T.	0.0
ringfield, Mo.	1,324	98	104	28.66	30.06	+.01	62.6	+4.4	85	10	71	36	31	54	24	54	50	70	2.53	−0.5	10	6,718	s.	30	w.	29	14	7	10	4.6	0.0	0.0
la	984	11	50	29.00	30.04	.00	63.7	+5.9	91	10	74	33	31	54	30	----	----	----	2.05	−0.9	11	3,788	s.	20	s.	26	13	6	12	5.4	0.0	0.0
›peka	987	92	107	------	------	------	61.4	+4.4	90	10	70	39	31	52	29	----	----	----	2.55	+0.1	8	6,447	s.	31	w.	26	13	8	10	4.7	0.0	0.0
ncoln	1,189	11	81	28.74	30.01	−.02	59.0	+4.8	91	10	69	35	31	49	39	51	47	70	1.56	−0.3	6	7,169	s.	33	nw.	29	13	7	11	5.1	0.0	0.0
naha	1,105	115	122	28.83	30.01	−.02	59.2	+4.9	89	10	68	36	30	50	33	51	46	69	2.61	+0.4	7	5,187	s.	27	nw.	27	12	12	7	4.5	0.0	0.0
ılentine	2,598	47	54	27.31	30.03	+.02	52.6	+3.3	84	19	65	23	31	40	43	44	37	64	0.55	−0.6	6	6,326	n.	33	w.	26	13	8	10	5.0	0.1	0.0
›ux City	1,135	94	164	28.78	29.99	−.03	55.8	+4.9	85	10	65	34	17	47	32	49	44	71	1.14	−0.6	6	8,813	nw.	42	s.	26	12	8	11	5.2	T.	0.0
ıron	1,306	59	74	28.59	30.00	−.01	52.5	+4.8	84	2	63	31	31	42	37	45	39	70	1.19	−0.1	9	6,980	s.	40	nw.	27	14	5	12	4.9	T.	0.0
erre	1,572	70	75	28.31	29.98	−.03	53.6	+3.8	88	5	65	23	31	42	39	45	37	63	0.41	−0.4	5	6,164	nw.	39	nw.	27	15	7	9	4.6	T.	0.0
ınkton	1,233	49	57	28.68	30.00	−.01	55.2	+4.1	83	2	65	32	31	46	34	----	----	----	1.62	+0.2	8	5,224	nw.	32	w.	27	12	8	11	5.3	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							48.0	+2.8										59	0.72	−0.3										4.1		
Billings	3,140	5	----		------	------	44.8	------	80	1	58	21	30	31	49	----	----	----	1.12	------	5	------	nw.	----	------	----	18	7	6	----	0.0	0.0
Havre	2,505	11	44	27.36	30.01	+0.03	47.5	+3.0	83	1	64	17	30	32	47	36	25	49	0.02	−0.6	2	6,033	sw.	34	nw.	26	20	7	4	2.8	T.	0.0
Helena	4,110	87	112	25.83	30.05	+.02	47.4	+2.5	73	2	59	27	11	36	37	38	28	52	0.09	−0.8	2	5,104	sw.	28	sw.	26	16	8	7	4.1	T.	0.0
Kalispell	2,973	48	56	26.99	30.07	+.06	44.2	+0.7	74	1	56	24	8	32	38	38	32	69	0.44	−0.6	5	3,106	nw.	28	sw.	23	15	7	9	4.2	T.	0.0
Miles City	2,371	48	55	27.50	30.07	+.07	49.4	+2.9	80	1	64	22	31	35	44	40	32	57	0.23	−0.6	3	3,857	s.	29	nw.	23	14	13	4	3.6	0.0	0.0
Rapid City	3,259	50	58	26.63	30.05	+.04	51.8	+3.3	84	1	64	16	31	40	44	41	32	54	0.79	−0.2	6	5,921	w.	35	nw.	29	17	6	8	4.0	0.7	0.0
Cheyenne	6,088	84	101	24.05	30.03	+.02	47.4	+2.6	75	1	60	22	30	35	37	38	29	55	1.07	+0.1	5	8,148	w.	53	w.	26	14	10	7	4.4	0.5	0.0
Lander	5,372	60	68	24.70	30.07	+.03	47.5	+4.0	76	1	61	25	27	34	39	39	33	66	1.62	+0.3	6	2,909	sw.	33	sw.	26	15	9	7	4.1	2.6	0.0
Sheridan	3,790	10	47	26.13	30.06	------	46.8	------	79	3	62	22	31	32	44	38	32	67	1.78	+0.7	5	2,659	nw.	25	nw.	26	15	12	4	4.0	T.	0.0
Yellowstone Park	6,241	11	48	23.94	30.11	+.09	42.0	+0.5	68	2	54	22	11	30	38	33	25	59	0.78	−0.6	6	4,151	sw.	31	sw.	23	10	10	11	5.3	1.4	0.0
North Platte	2,821	11	51	27.09	30.02	.00	55.0	+5.3	84	5	69	17	31	41	39	44	37	61	0.34	−0.7	7	4,868	s.	34	nw.	26	13	11	7	4.6	0.6	0.0
Middle Slope							60.6	+4.7										58	1.14	−0.6										3.9		
Denver	5,292	106	113	24.77	30.02	+.01	54.0	+2.8	84	9	66	23	30	42	42	41	29	46	0.63	−0.4	6	4,529	s.	33	w.	26	15	8	8	4.2	T.	0.0
Pueblo	4,685	80	86	25.34	30.01	+.02	56.1	+4.1	85	9	72	20	31	40	48	42	30	45	0.13	−0.5	3	3,881	nw.	34	w.	26	19	9	3	3.3	0.0	0.0
Concordia	1,392	50	58	28.57	30.04	+.01	60.4	+4.5	93	10	71	32	31	50	40	52	47	71	2.50	+0.5	8	5,790	s.	32	nw.	10	13	14	4	4.5	T.	0.0
Dodge City	2,509	88	100	27.45	30.04	+.02	61.0	+4.9	93	6	74	19	31	48	37	49	41	58	0.56	−0.7	4	9,180	s.	47	n.	10	23	5	3	2.7	0.0	0.0
Wichita	1,358	139	158	28.60	30.02	−.01	64.2	+5.6	94	6	74	30	31	55	31	54	48	63	1.19	−1.4	6	8,329	s.	48	s.	26	12	13	6	4.6	0.0	0.0
Oklahoma City	1,214	10	47	28.76	30.03	.00	68.0	+6.5	96	4	78	32	31	58	31	58	52	66	1.83	−1.0	9	5,897	s.	24	s.	26	15	8	8	4.1	0.0	0.0
Southern Slope							68.7	+5.5										58	2.88	+1.1										3.2		
Abilene	1,738	10	52	28.23	30.02	+.01	70.8	+5.4	98	7	82	40	31	60	30	60	54	67	10.21	+7.7	6	5,837	s.	26	s.	26	17	7	7	3.9	0.0	0.0
Amarillo	3,676	10	49	26.32	30.02	+.02	63.3	+5.6	91	5	76	32	31	50	36	50	42	57	0.92	−0.7	4	5,767	s.	22	sw.	26	23	3	5	2.5	0.0	0.0
Del Rio	944	64	71	28.97	29.94	−.04	77.2	+7.2	96	7	88	52	31	67	29	65	58	59	0.01	−1.8	1	5,608	se.	22	se.	11	18	10	3	3.4	0.0	0.0
Roswell	3,566	75	85	26.41	29.99	+.03	63.3	+3.8	90	6	78	31	30	49	41	50	39	50	0.37	−1.0	3	4,294	s.	27	nw.	20	19	9	3	2.9	0.0	0.0
Southern Plateau							62.9	+2.9										50	0.45	−0.2										3.2		
El Paso	3,778	152	175	26.20	29.93	+.01	70.0	+6.5	91	10	82	44	31	58	39	52	39	37	0.14	−0.7	2	5,497	e.	30	w.	20	22	7	2	2.1	0.0	0.0
Albuquerque	4,972	51	66	25.10	29.95	------	59.0	------	82	10	73	30	30	45	39	47	37	53	0.57	------	4	3,456	ne.	25	se.	11	22	5	4	3.1	0.0	0.0
Santa Fe	7,013	38	53	23.33	29.99	+.03	52.8	+2.4	73	10	64	27	30	42	30	42	34	56	1.10	−0.1	6	4,117	se.	21	n.	28	17	10	4	3.4	T.	0.0
Flagstaff	6,907	10	59	23.40	29.96	+.04	48.6	+3.9	70	3	65	21	31	32	46	38	----	63	1.43	------	5	4,938	nw.	26	sw.	18	18	11	2	----	0.0	0.0
Phoenix	1,108	10	107	28.75	28.89	+.01	72.8	+2.2	97	8	88	49	28	58	43	56	42	40	0.22	−0.2	1	2,661	e.	19	s.	9	23	6	2	1.9	0.0	0.0
Yuma	141	9	54	29.75	29.90	+.03	73.5	+0.2	97	4	88	49	20	59	40	58	48	48	0.09	−0.2	2	2,796	n.	21	nw.	18	26	4	1	1.1	0.0	0.0
Independence	3,957	6	27	25.97	29.99	+.04	59.5	+2.0	82	3	75	35	27	44	40	45	----	----	0.69	+0.4	2	------	s.	----	------	----	17	10	4	----	0.0	0.0
Middle Plateau							54.0	+3.8										48	0.60	−0.2										3.8		
Reno	4,532	74	81	25.48	29.97	−.02	54.8	+5.1	82	1	70	28	27	39	42	42	29	44	0.19	−0.2	1	3,708	sw.	42	sw.	25	18	11	2	2.9	0.0	0.0
Tonopah	6,090	12	20	------	------	------	54.6	------	78	3	64	30	26	45	28	42	30	45	0.48	------	3	------	se.	----	------	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.64	30.02	−.03	51.8	+3.5	82	2	70	24	27	34	51	39	26	44	0.29	−0.3	3	4,832	ne.	36	sw.	22	20	7	4	3.1	T.	0.0
Modena	5,473	10	43	24.65	29.98	+.02	50.6	+2.6	76	16	65	23	27	36	44	40	30	55	0.87	+0.1	5	5,793	w.	35	nw.	26	14	10	7	4.0	0.0	0.0
Salt Lake City	4,360	163	203	25.65	30.00	−.01	56.6	+4.1	78	9	66	31	27	47	29	45	35	47	0.57	−0.9	5	4,899	se.	39	nw.	26	8	15	8	5.3	0.0	0.0
Grand Junction	4,602	60	68	25.42	30.00	+.01	56.4	+3.6	82	9	68	29	28	44	35	45	35	51	1.07	+0.1	6	3,422	se.	30	w.	26	17	8	6	3.6	0.0	0.0
Northern Plateau							51.6	+1.6										58	0.88	−0.2										4.6		
Baker	3,471	48	53	26.50	30.09	+.01	47.4	+0.8	76	1	61	25	21	34	42	39	30	55	0.41	−0.5	6	3,849	se.	23	se.	22	14	10	7	4.0	0.1	0.0
Boise	2,739	79	87	27.20	30.07	+.01	53.8	+2.7	81	2	66	35	21	42	36	44	34	53	0.43	−0.8	7	2,566	se.	18	n.	5	14	0	11	4.5	T.	0.0
Lewiston	757	40	48	29.26	30.08	+.01	52.8	+1.3	87	1	66	32	9	40	41	----	----	----	1.17	−0.1	8	1,574	w.	19	nw.	2	14	10	7	4.4	0.0	0.0
Pocatello	4,477	60	68	25.52	30.04	.00	51.2	+2.8	76	1	63	32	30	40	39	41	33	58	1.51	+0.4	8	4,516	se.	33	sw.	26	12	7	12	5.5	T.	0.0
Pasco	416	5	33	------	------	------	52.1	------	87	1	07	25	21	37	46	----	----	01	0.65	------	4	4,655	nw.	----	------	----	15	5	11	----	0.0	0.0
Spokane	1,929	101	110	28.01	30.07	+.01	49.4	+1.1	80	1	61	30	21	38	37	42	35	63	0.82	−0.4	7	2,982	s.	24	sw.	23	13	11	7	4.3	0.0	0.0
Walla Walla	991	57	65	28.98	30.05	−.02	54.0	+0.5	86	1	64	37	21	44	33	47	38	58	1.51	0.0	6	2,606	se.	20	se.	22	13	7	11	5.0	0.0	0.0
Yakima	1,076	58	67	28.90	30.06	------	52.4	+2.2	82	1	64	31	24	40	37	44	35	57	0.33	−0.3	7	2,950	nw.	24	sw.	22	16	8	7	4.2	0.0	0.0
North Pacific Coast Region							53.2	+1.0										78	3.63	0.0										6.3		
North Head	211	11	56	29.82	30.05	.00	52.8	−0.1	76	14	57	43	21	48	24	51	49	89	5.69	−0.7	14	9,208	n.	66	s.	21	6	7	18	6.9	0.0	0.0
Port Angeles	29	8	53	------	30.05	------	49.9	------	65	1	57	37	8	43	22	----	----	----	1.16	−1.2	11	3,454	s.	24	w.	26	8	8	15	----	0.0	0.0
Seattle	125	215	250	29.91	30.04	−.01	52.5	+1.1	69	15	58	40	21	46	25	49	47	81	3.09	+0.2	14	4,749	s.	30	s.	23	9	8	14	6.0	0.0	0.0
Tacoma	194	172	201	29.84	30.05	+.01	51.4	+0.9	71	16	58	37	8	44	28	----	----	----	3.93	+0.6	14	4,129	s.	26	n.	7	6	7	18	7.2	0.0	0.0
Tatoosh Island	86	9	53	29.92	30.01	.00	51.8	+1.9	64	15	55	43	10	48	14	50	48	89	5.76	−2.4	14	9,524	e.	47	s.	26	6	5	20	7.3	0.0	0.0
Medford	1,329	29	58	28.62	30.03	------	54.2	------	89	1	69	31	7	39	47	46	39	63	1.74	+0.4	8	2,906	s.	30	se.	21	13	10	8	4.7	0.0	0.0
Portland, Oreg	153	68	106	29.89	30.05	−.01	55.8	+1.6	79	15	64	39	21	48	28	51	47	76	4.32	+1.2	12	3,498	nw.	17	e.	29	7	10	14	6.1	0.0	0.0
Roseburg	510	75	99	29.51	30.06	−.02	54.7	+0.8	85	1	66	37	4	44	38	49	44	71	3.34	+0.7	10	2,257	n.	23	sw.	22	9	11	11	5.0	0.0	0.0
Middle Pacific Coast Region							59.7	−0.6										63	0.76	−0.5										4.2		
Eureka	62	73	89	30.00	30.07	+.01	53.6	0.0	68	29	59	42	26	48	20	51	49	86	2.28	0.0	7	3,348	nw.	34	sw.	22	6	8	17	6.6	0.0	0.0
Red Bluff	330	5	58	29.62	29.97	−.06	63.4	−0.9	98	1	77	40	26	50	41	52	41	49	0.57	−0.8	3	3,712	nw.	29	se.	22	19	0	6	3.4	0.0	0.0
Redding	722	20	34	------	------	------	64.9	------	96	1	70	40	26	54	30	----	----	42	3.13	------	3	5,099	nw.	----	------	----	15	7	9	----	0.0	0.0
Sacramento	69	106	117	29.91	29.98	−.01	62.0	−0.9	95	1	74	39	26	49	38	54	48	64	0.18	−0.7	2	4,515	s.	23	nw.	18	27	1	3	1.8	0.0	0.0
San Francisco	155	208	243	29.85	30.02	+.01	59.8	−0.7	83	1	66	49	26	53	26	53	50	76	0.68	−0.4	3	4,100	sw.	22	w.	10	9	13	9	5.2	0.0	0.0
San Jose	141	12	110	29.88	30.03	------	59.8	−0.5	92	1	72	39	27	48	42	----	----	----	0.10	−0.0	2	3,507	nw.	22	se.	22	18	7	6	3.8	0.0	0.0
South Pacific Coast Region							67.0	+2.6										61	0.04	−0.6										3.1		
Fresno	327	89	98	29.63	29.98	+.02	65.5	+1.5	93	2	79	42	27	52	37	53	41	47	T.	−0.6	0	3,513	nw.	26	nw.	25	23	7	1	2.1	0.0	0.0
Los Angeles	338	159	191	29.62	29.98	+.03	68.8	+3.5	94	28	78	52	10	60	29	57	50	61	0.06	−0.6	3	2,935	w.	20	ne.	1	18	5	8	3.3	0.0	0.0
San Diego	87	62	70	29.87	29.96	−.01	66.6	+2.9	93	1	74	54	27	60	29	60	56	74	0.05	−0.5	1	3,517	nw.	24	n.	1	15	13	3	3.9	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.85	29.93	------	80.4	+0.6	92	21	86	73	28	75	18	----	----	----	6.40	+0.5	23	6,147	e.	40	e.	10	7	18	6	5.5	0.0	0.0
Panama Canal																																
Balboa Heights	118	0	97	------	[1] 29.80	−.02	80.4	+1.2	91	11	86	72	25	74	17	----	----	[1] 87	9.26	−0.9	20	3,879	nw.	24	s.	18	0	8	23	8.1	0.0	0.0
Cristobal	36	6	97	------	[1] 29.81	−.02	82.0	+2.2	91	16	88	74	25	76	16	76	75	[1] 83	20.42	+5.0	26	4,352	se.	25	n.	12	0	7	24	8.3	0.0	0.0
Alaska																																
Fairbanks	455	11	44	------	[2] 29.60	------	23.1	------	44	17	31	−10	20	15	27	----	----	81	0.82	------	10	1,922	ne.	15	sw.	15	6	4	21	----	4.0	2.2
Juneau	80	11	50	[2] 29.60	[2] 29.75	------	43.4	------	55	4	47	30	27	40	17	41	37	79	15.91	------	24	5,806	se.	28	se.	31	3	6	22	8.2	0.4	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.95	[2] 29.99	------	77.0	+0.8	85	11	82	68	29	73	15	71	69	76	2.33	+0.8	11	5,067	e.	24	ne.	21	7	14	10	5.7	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

Table 2.—*Data furnished by the Canadian Meteorological Service, October, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
ape Race, N. F	99												
'dney, C. B. I	48	29.90	29.95	−.01	49.8	+3.3	58.0	41.7	72	32	2.44	−2.25	0.0
alifax, N. S	88	29.83	29.94	−.02	50.3	+3.1	58.2	42.3	69	31	3.80	−1.75	T.
armoutb, N. S	65	29.83	29.90	−.12	51.1	+3.5	58.6	43.6	71	34	4.55	+0.43	0.0
iarlottetown, P. E. I	38	29.82	29.86	−.10	49.4	+2.9	55.5	43.3	69	34	2.19	−2.71	0.0
iatham, N. B	28	29.81	29.84	−.12	47.5	+4.5	56.6	38.5	76	27	5.00	+1.14	0.0
ither Point, Que	20												
iebec, Que	296	29.62	29.94	−.06	47.4	+5.0	54.4	40.4	75	31	4.49	+1.34	0.0
)ucet, Que	1,236				42.9		52.7	33.2	77	17	4.17		3.1
ontreal, Que	187	29.74	29.95	−.06	51.3	+6.5	58.1	44.6	76	35	3.91	+0.78	0.0
tawa, Ont	236	29.71	29.97	−.04	52.2	+8.4	62.6	41.8	82	30	1.75	−0.80	T.
ngston, Ont	285	29.70	30.01	−.02	53.1	+6.1	60.1	46.1	73	32	2.51	−0.22	0.0
ronto, Ont	379	29.62	30.03	−.01	53.1	+6.5	61.1	45.2	77	34	1.99	−0.37	0.0
chrane, Ont	930				46.2		54.4	37.9	78	27	3.75		T.
hite River, Ont	1,244	28.60	29.92	−.06	44.3	+7.2	54.4	34.3	76	18	3.49	+1.14	0.0
ndon, Ont	808				52.7		62.9	42.6	80	30	2.06		T.
uthampton, Ont	656	29.30	30.02	.00	52.6	+6.5	61.3	41.0	78	32	3.50	+0.33	T.
rry Sound, Ont	688	29.30	30.00	−.01	50.6	+6.7	57.8	43.4	75	30	3.77	−0.15	0.0
rt Arthur, Ont	644	29.22	29.93	−.05	49.8	+9.9	57.1	42.5	73	31	7.80	+5.24	0.0
innipeg, Man	760												
nnedosa, Man	1,690	28.12	29.95	−.02	43.9	+6.1	55.3	32.6	78	24	0.63	−0.57	T.
Pas, Man	860				43.2		53.1	33.3	68	26	1.91		0.7
Appelle, Sask	2,115	27.66	29.92	−.05	43.6	+4.2	54.7	32.6	74	20	0.48	−0.62	T.
)ose Jaw, Sask	1,759				45.4		58.3	32.4	77	18	0.39		0.0
ift Current, Sask	2,392	27.37	29.90	−.07	45.0	+2.9	59.5	30.5	78	8	0.16	−0.72	0.0
dicine Hat, Alb	2,365												
lgary, Alb	3,540												
nff, Alb	4,521	25.36	29.95	.00	40.8	+1.5	51.9	29.6	67	18	0.57	−0.45	3.1
nce Albert, Sask	1,450	28.36	29.95	−.02	43.8	+6.7	55.3	32.3	70	23	0.15	−0.68	T.
ttleford, Sask	1,592	28.18	29.93	−.04	42.4	+2.8	55.6	29.2	73	16	0.49	+0.04	0.0
monton, Alb	2,150												
mloops, B. C	1,262	28.72	30.02	+.06	47.0	0.0	56.1	38.0	78	30	0.52	−0.09	0.0
torla, B. C	230	29.78	30.04	+.03	51.4	+2.2	56.4	46.4	68	43	1.77	−0.60	0.0
rkerville, B. C	4,180												
evan Point, B. C	20				48.8		54.1	43.5	59	37	11.21		0.0
nce Rupert, B. C	170												
milton, Ber	151	29.96	30.12	+.10	74.7	+1.7	80.4	69.0	90	62	4.21	−2.50	0.0

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INFLUENCES OF LAKE MICHIGAN ON EAST AND WEST SHORE CLIMATES [1]

By Clarence Burt Odell

[Geography Department, University of Nebraska, Lincoln, Nebr., November, 1931]

The influence of Lake Michigan upon the climate of the eastern shore in making it a region favorable to fruit growing is generally understood. However, little in the way of quantitative proof in the form of graphs from weather reports has been attempted. In view of the fact that there is general knowledge pertaining to the differences in climate upon the opposite shores of the lake it has been considered of enough importance to take averages of 15 years of weather reports for stations situated on the east and west shores, in approximately the same latitudes, and to put these results into graphic form. The stations of Milwaukee and Grand Haven were used as one pair and the stations at Green Bay and Ludington as another; thus, the matter of latitude need not be considered, since these pairs are located near the same parallels.

The climatic factors used in the graphs were temperature, wind velocity, number of clear days and cloudy days, precipitation, and the number of days with snow. The number of times that the minimum temperature fell below certain critical points was counted and used in three graphs in order to show which side of the lake is more favorable to fruit culture as far as temperatures are concerned. The critical temperatures for peaches were used, and the estimated damaging temperatures were obtained through consultation with the pomology department of the University of Illinois. A long discussion of each of the graphs and of the why's and wherefore's is not necessary because a study of the figures will bring out very clearly the striking influence of this body of water. Somewhat similar differences are noted between east and west shores at both pairs of stations and these differences in climate may be assigned to the influences of the lake in spite of its relatively small size.

TEMPERATURE

There seems to be a greater range of temperature at the west shore stations—Green Bay and Milwaukee—than at the eastern. (Figs. 5 and 6.) The range, however, is naturally greater at the two northern stations. Grand Haven and Ludington are warmer in the winter and cooler in the summer than Milwaukee and Green Bay. This is due to the winds coming over the water which is cooler than the land in the summer and warmer for the most part in the winter, a result of the difference in the rate of heating and cooling of land and water. There is also a slightly more rapid increase of temperature in the spring and decrease in the fall at Milwaukee and Green Bay than on the eastern shore, due, probably, to the same reason.

The temperature is more nearly uniform at Ludington during July and August than at Green Bay, another apparent water influence. The prevailing wind is south for the two stations during both months.

An attempt also has been made to show how favorable the temperatures are to grow good peach crops on the Michigan and Wisconsin shores of Lake Michigan. Data were taken from the Climatological Data and the following figures were used as the minimum critical temperatures [2] (° F.) which would damage the fruit:

	° F.
January	−15
February	−10
March	5
April	15
May	28

In each of these months for 15 years (1914–1928 inclusive) the number of times was recorded in which the temperature fell below these critical points and the totals were compared. The graphs show the results and it can be seen that Ludington and Grand Haven had fewer killing temperatures and also had more years that were entirely free from damaging temperatures than Green Bay and Milwaukee stations. It does not necessarily follow, however, that the years recorded without such temperatures had good peach crops. Many other factors enter into the production of the fruit—likewise with the other crops grown. Some of these items are wind, rain, soil temperatures, temperatures during the preceding fall and winter, amount of snow covering, amount of sunshine, and humidity. The exposure of the orchard and its drainage, both soil and air, will greatly affect the setting of the fruit. However, the temperature conditions are of fundamental importance to growth, insect flight, rainfall, and humidity.

Figure 1 shows that Green Bay had killing or damaging temperatures in 14 out of the 15 years; Ludington, only 7; Milwaukee, 11 out of the 15; and Grand Haven, only 9. Thus the chances for a damaged crop from too low a temperature are approximately 30 per cent greater on the west shore than on the east. Also the total number of times that the temperatures fell below the critical temperatures were much greater in Green Bay and Milwaukee than at the east shore stations. Here, then, is one important reason why peaches may be grown on the Michigan shore and not on the Wisconsin shore.

However, it must not be assumed that there are no peach crops except in the years entirely free from damaging temperatures. In many of the years when the mercury fell only once or twice below the critical temperature

[1] The weather data used were obtained from the annual reports of the chief of the United States Weather Bureau for the 15-year period of 1914–1928, inclusive. The data used in the section on critical temperatures were obtained from the monthly and daily records found in the Climatological Data (1914–1928, inclusive) for the months January through May. The Michigan Department of Agriculture furnished data on the actual crop condition or production percentages.

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[2] Figures by Dr. J. M. Dorsey, professor of pomology, University of Illinois, Urbana, Ill.

it would not necessarily damage the whole crop. Perhaps just one section of an orchard or even parts of the trees might be damaged and the rest unhurt. The temperatures as given in the records are for the immediate vicinity of the Weather Bureau station and it is entirely possible that that reading might be found only in the station's instrument shelter. Even in the same orchard, or perhaps on the same tree, air drainage might cause a section to be damaged and the rest to be unharmed. Also, there are so many factors influencing the setting of the fruit that it must not be assumed that there was a perfect peach crop every year in which no damaging temperatures were recorded any more than that the entire crop was destroyed in the years with critical temperatures.

Of course the killing temperatures are different for various fruits but the peach is rather sensitive to low temperatures so that this study may be applied to all fruits grown in the region with some degree of accuracy. The Michigan peach regions center about Ludington and Grand Haven. Hence, the data here used are fairly representative of the conditions in the orchards. Peaches are not grown near Green Bay or Milwaukee and the data obtained from those stations show why that industry would not be profitable there.

Figure 2 (sections A, B, C, D) shows the number of times the temperature fell below the critical point each month for each of the stations. The month of March seems to be the one with the greatest number of times with damaging temperatures. The damage done by the cold in March will depend upon the weather in the preceding months and upon the growth of the tree at the time of the low temperature.

The two graphs (figs. 5 and 6) giving the average temperatures for the four stations show that spring is retarded on the east shore; therefore the trees should not be so far advanced as on the west shore, and hence, a low temperature would not do so much damage to the trees near Ludington and Grand Haven, as on the west coast.

In Figure 3, annual occurrence of critical temperatures, the figures on the right are the number of years during the 15 in which there were the same number of temperature drops below the critical points. This will indicate to a certain degree just how severe the temperatures were for the various years, and also how different the conditions are at the four stations. Thus, in Green Bay we find that in three different years damaging temperatures were recorded fifteen times and that but one year was entirely free. Milwaukee had three with five or more times below the killing point. Ludington had seven years entirely free with but one year as high as five times. Grand Haven had six free years and only two years as many as four times below the damaging point. This all indicates greater freedom from this great danger in western Michigan and the advantage of this section as a peach region over the eastern portion of Wisconsin.

Figure 4 showing the final condition, or production percentages, show some correlation with the last-mentioned one. When the number of occurrences of the critical temperatures goes down, the percentage of production goes up, and vice versa. A few exceptions may be noted, as in 1921, but they may possibly be explained by the other climatic factors. In 1921, however, according to the CLIMATOLOGICAL DATA for January to July, the reports indicate that there was an unusually mild winter. January, February, and March were mild and above normal, but April came in with a cold wave and also had blizzards in the middle of the month over the lower peninsula. Cherries, peaches, plums, apples, strawberries, and garden truck were badly frozen. The report also states that a cold wave came the 15th and 16th of May and that there was some damage since the vegetation was two weeks in advance of the normal season. In this case temperatures might not have been low enough to do harm in ordinary circumstances but due to the advanced season the buds were damaged at a temperature higher than 15° in April and 28° in May. It must be realized that these critical temperatures are only estimates and are used only as a basis for the study. Many variations of temperatures are possible whereby damage will be done to the growing fruit trees.

The fluctuations in production are not affected by temperature alone. The many other factors entering the problem, however, are somewhat dependent upon it. At Least the weather has much to do in bringing about conditions which will damage the fruit crop as well as in bringing about a good crop.

It is rather hard to specifically state how much damage is done to fruit in any one year and to determine an average annual loss. Figure 3 for the individual years shows that there is a great deal of irregularity in the frequency of killing temperatures. Nothing definite is possible in predictions—the place, according to the past weather records, with the greatest chances of being free from low temperature drops can be best used for a profitable fruit-growing region. The many factors entering into this decision makes the problem one of difficulty and yet one of extreme importance financially. Fruit growers want a large percentage of their trees to produce, and they will, of course, gamble with the weather in the places which have the lowest percentage of killing temperatures over a period of years. These graphs were made from past weather reports and should bring out graphically an important reason why the fruit region is where it is, and why the presence of the lake must certainly be an influencing factor in making the climate on the leeward side favorable for fruit culture. A brief account of other weather conditions, as influenced by the lake, follows.

WIND VELOCITY

The wind velocity naturally increases in the winter season on both sides of the lake, but the increase is more pronounced on the east side than on the west because of less friction between wind and lake surface (ice or water) than between wind and land. The velocity drops during the summer—to about 9 miles per hour in July and August for the four stations. (Figs. 7 and 8.) The difference in velocity between the two shores of the lake is more pronounced to the north than to the south.

NUMBER OF CLEAR DAYS AND CLOUDY DAYS

Winter is the season of greatest number of cloudy days on both sides of the lake, while summer is the period of greatest number of clear days. (Figs. 9 and 10.) There is a greater annual range in number of clear and cloudy days in the east than on the west side of the lake. December and January each have about seven more cloudy days on the east than on the west shore, while in the summer the difference in number of clear days is not so great. The trend for partly cloudy days would more nearly resemble that of clear than that of cloudy days.

PRECIPITATION

In total annual precipitation there is little difference between the two sides of the lake in the same latitude, but there is a rather striking difference in seasonal dis-

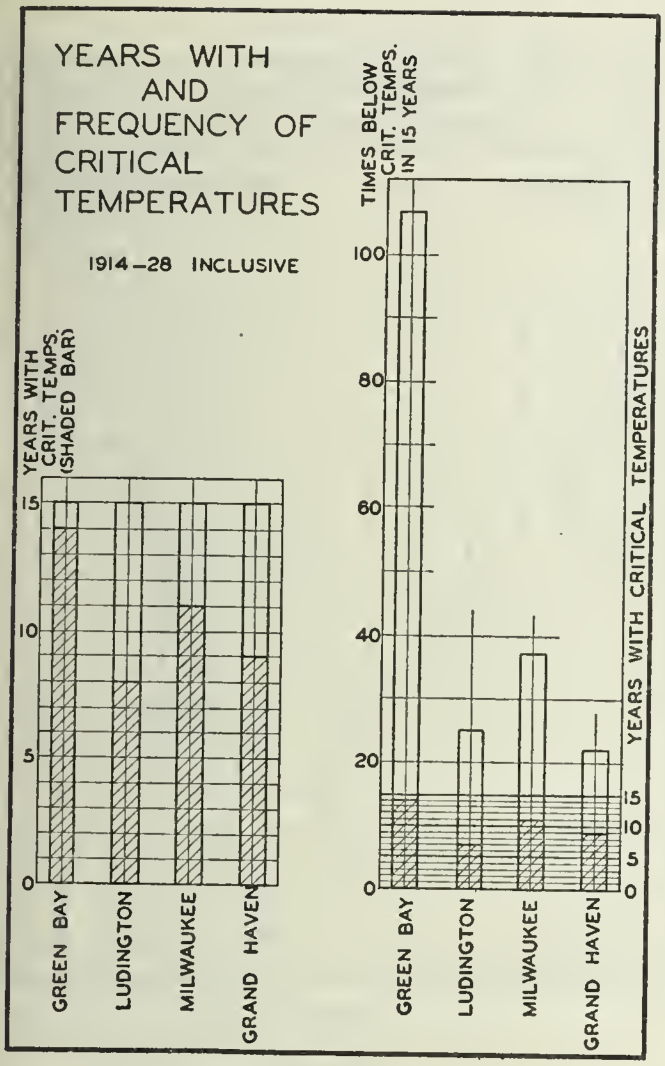


Figure 1

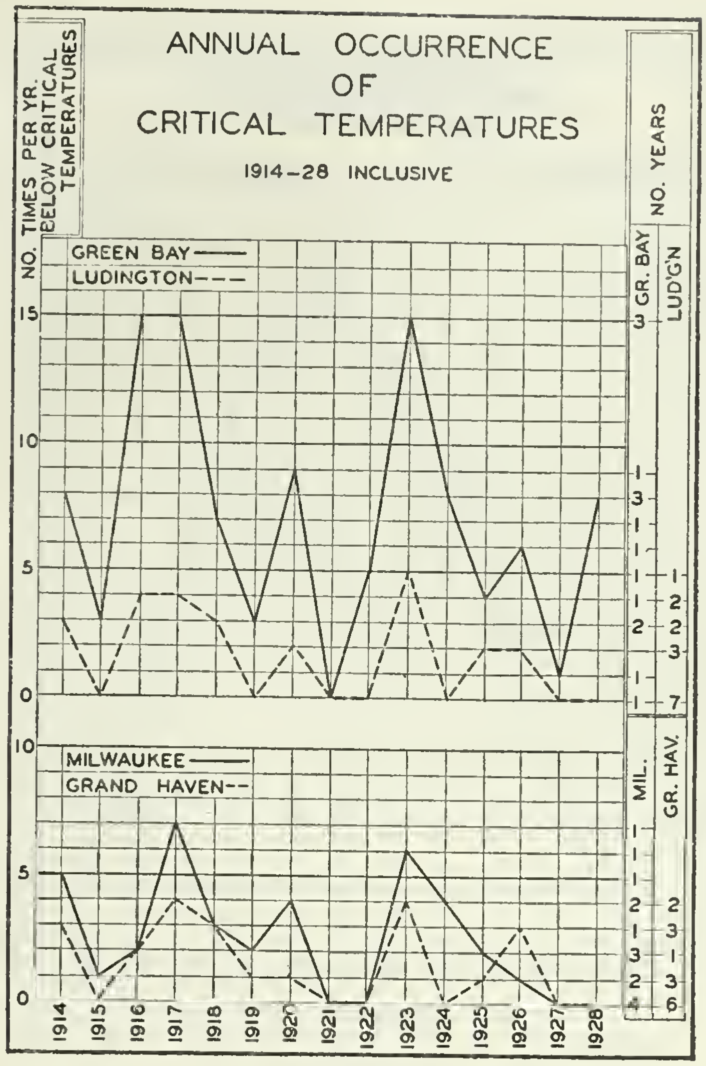


Figure 3

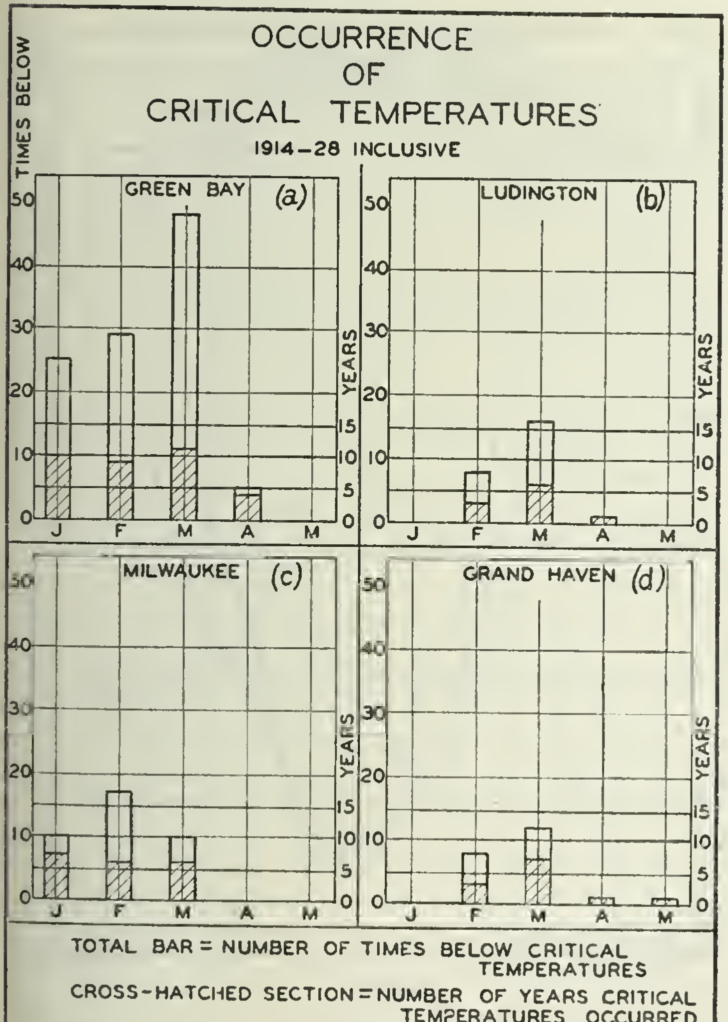
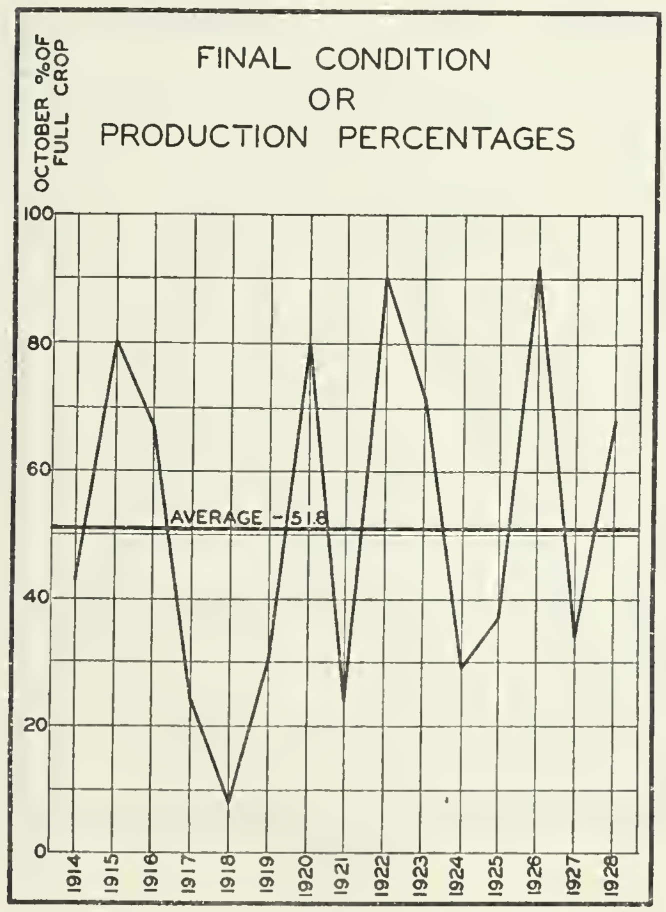


Figure 2



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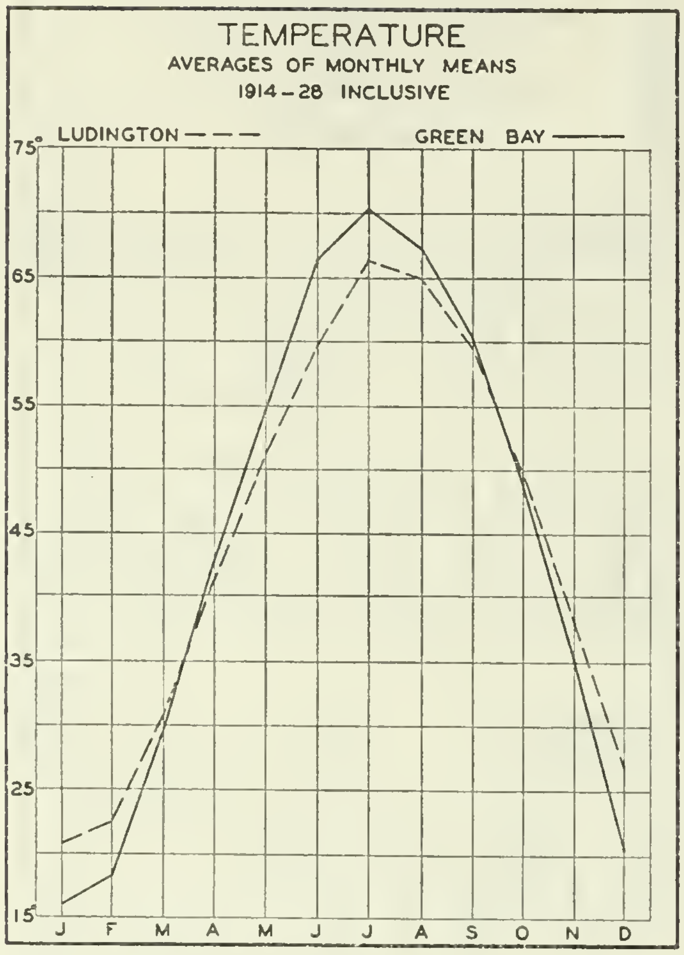

FIGURE 5

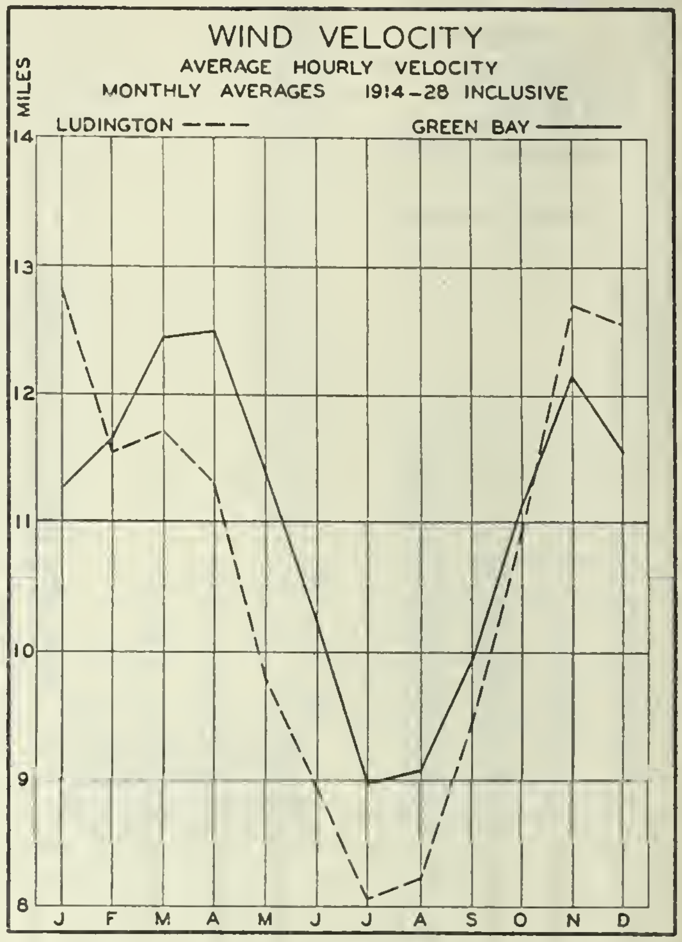

FIGURE 7

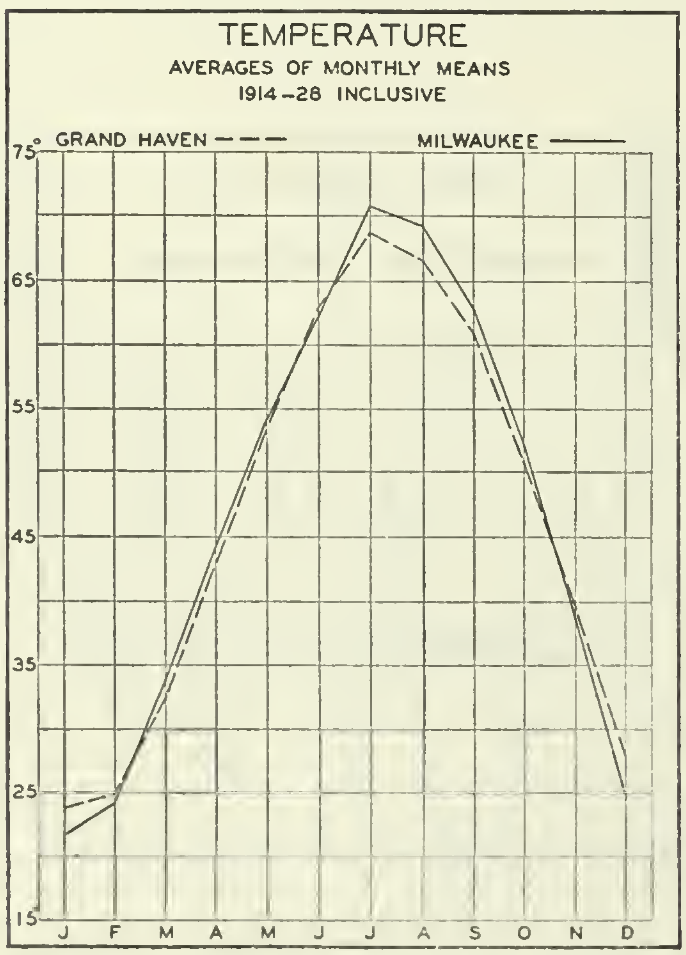

FIGURE 6

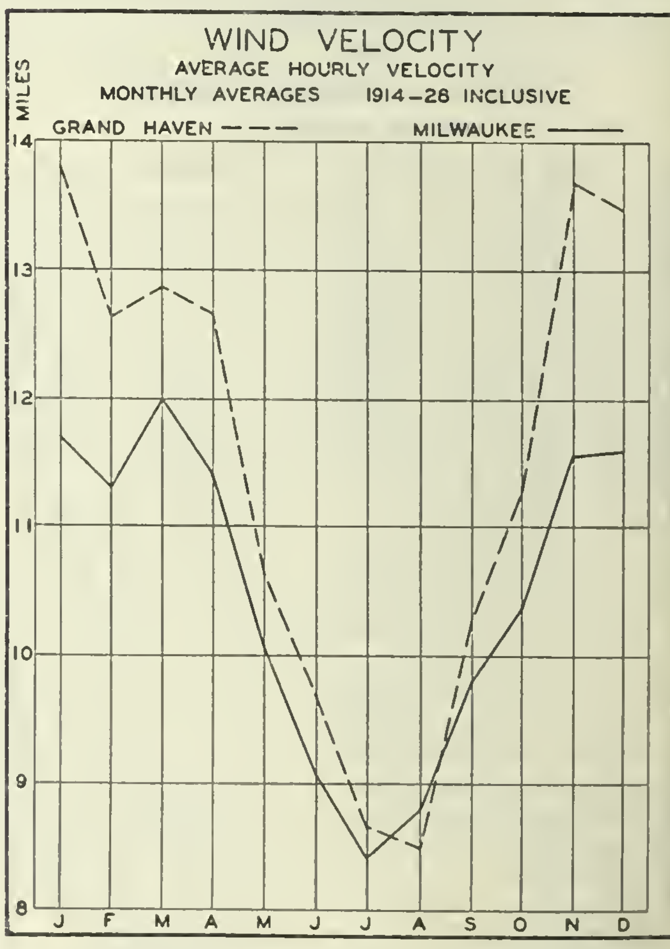

FIGURE 8

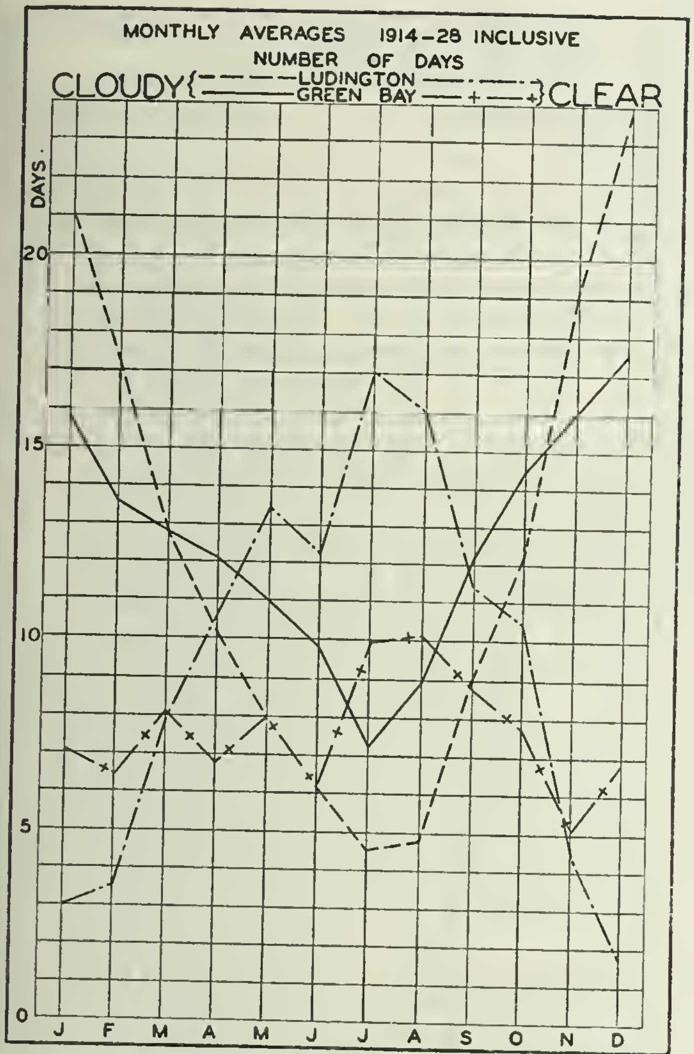

FIGURE 9

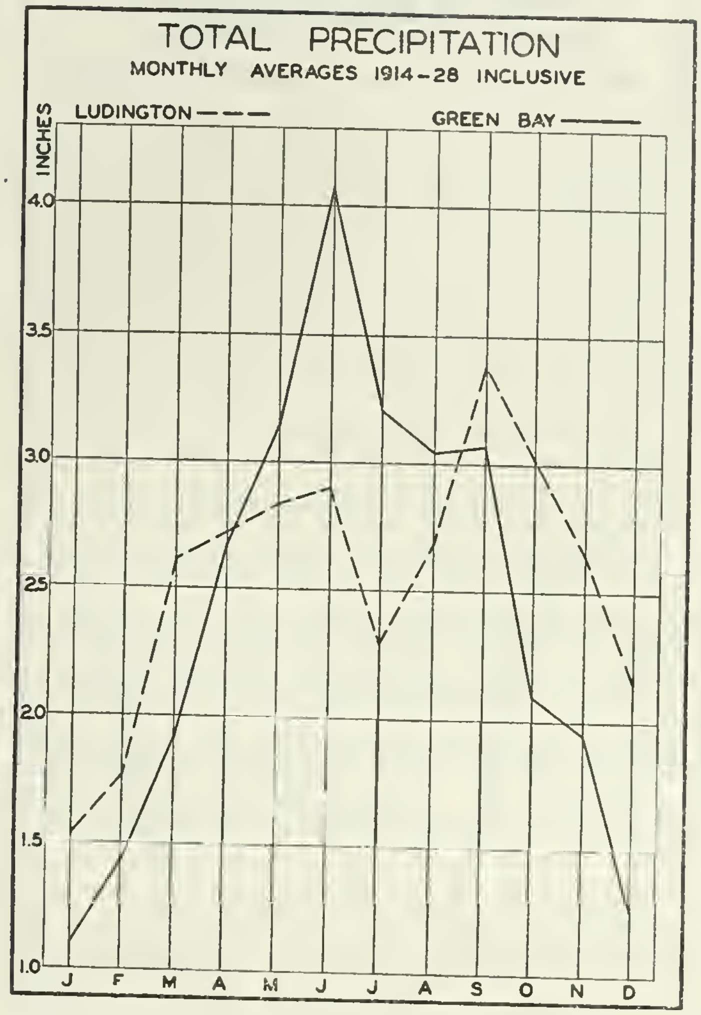

FIGURE 11

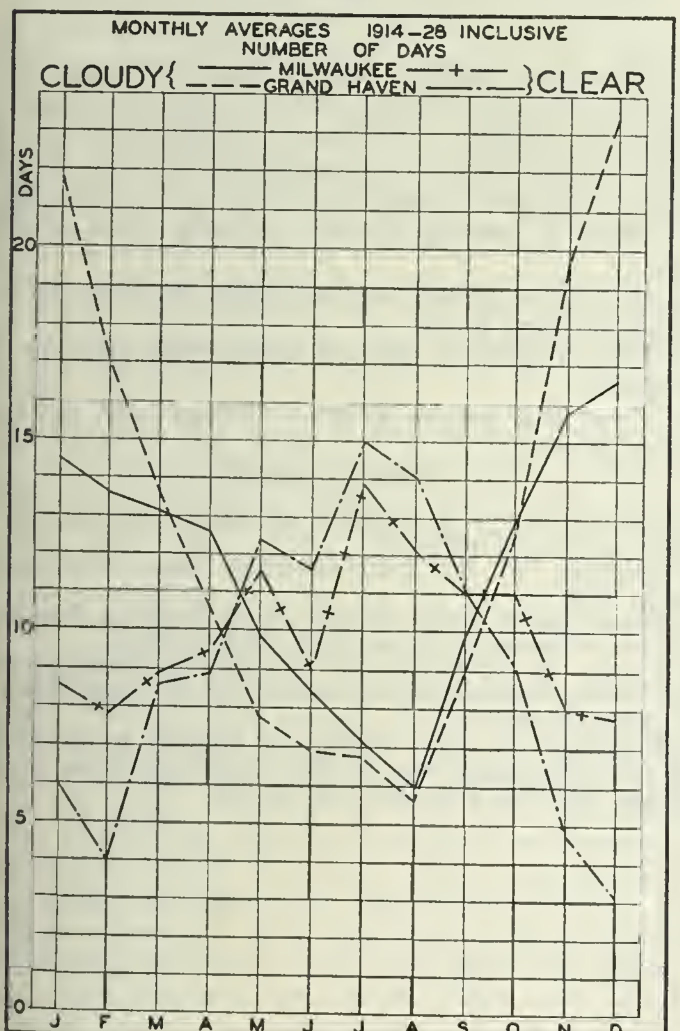

FIGURE 10

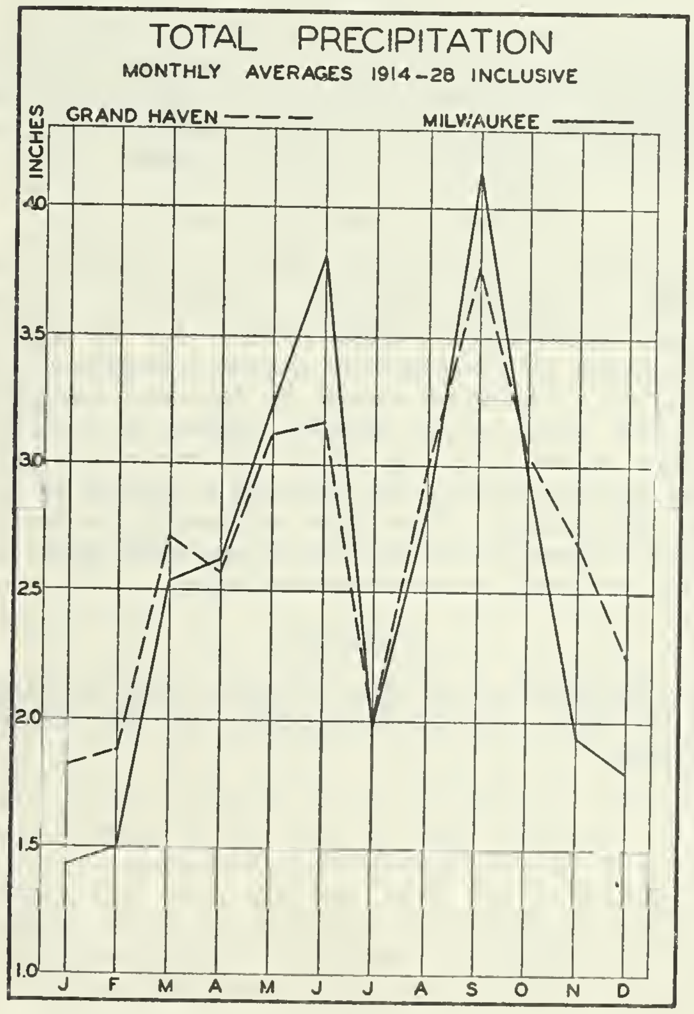

FIGURE 12

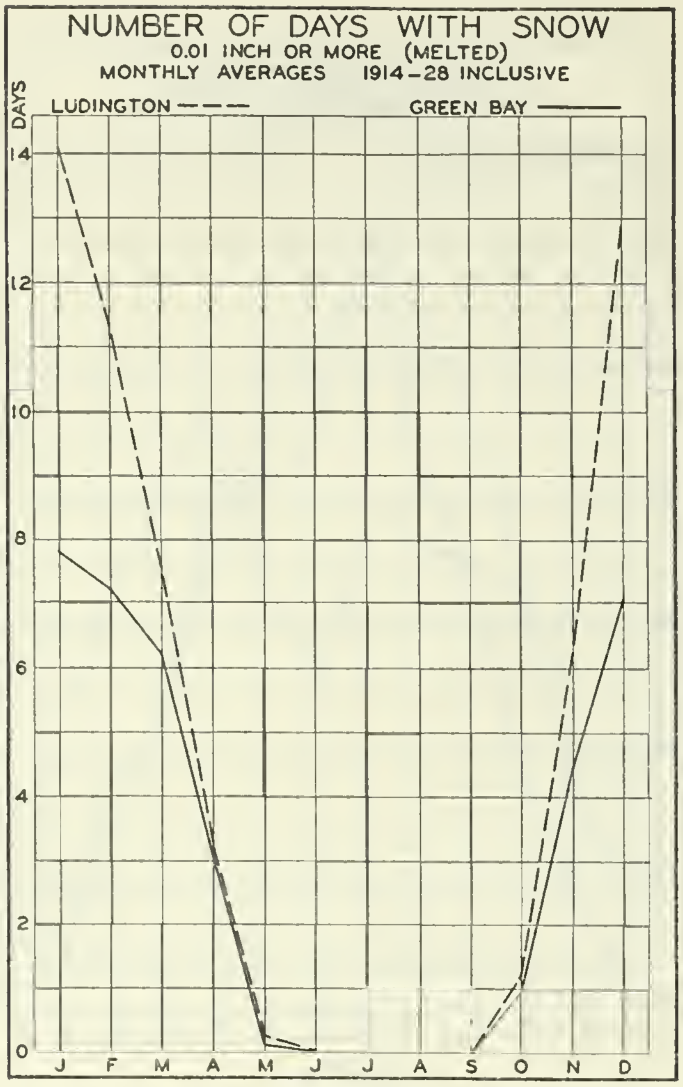

FIGURE 13

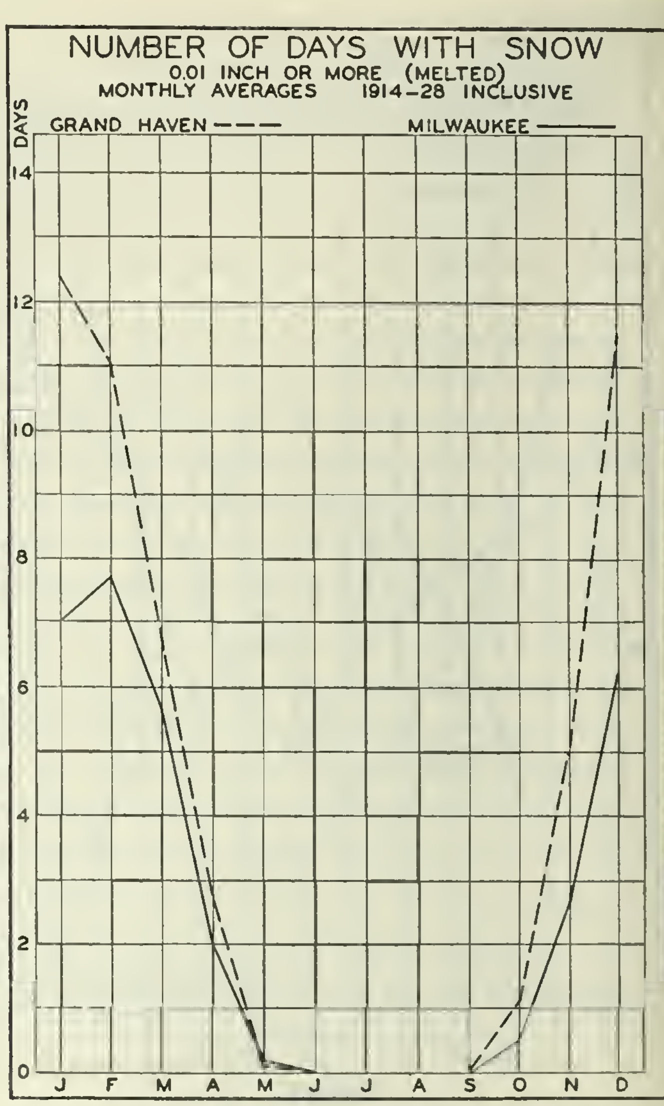

FIGURE 14

tribution. (Figs. 11 and 12.) Though both sides have a maximum in summer, June and September being the rainiest months, the east shore of the lake has a noticeably lower percentage of its precipitation in summer. This again is characteristic of marine climates.

NUMBER OF DAYS WITH SNOW

The greatest number of days with snow is found on the east side of the lake, especially in December, January, February, and March. (Figs. 18 and 14.) In terms of whole months all stations have the same length of snow-free period. The peak comes in January, except for Milwaukee where it is slightly higher in February. February would probably stand out even more prominently had the months been reduced to periods of equal length—30.44 days. West shore stations do not have so abrupt a decrease in the number of days with snow, from January to March, as east shore stations.

SUMMARY

Thus the influences of Lake Michigan upon the climate of its two shore may be summarized into the following statements,

1. There is a smaller annual range in temperature o east than on west shore, with a slight tendency for delayed maximum. Critical temperatures for peac production are far more numerous on the west shore wit March as the peak month on both sides of the lake.
2. There is a stronger winter westerly wind on the ea shore.
3. There is a greater annual range in clear and cloud days on the east shore.
4. There is greater fall and winter precipitation on th east shore.
5. There is a greater number of days with snowfall o the east shore.

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EASTERLY GALES IN THE COLUMBIA RIVER GORGE DURING THE WINTER OF 1930-1931—SOME OF THEIR CAUSES AND EFFECTS

By Donald C. Cameron

[Weather Bureau, Portland, Oreg., June 6, 1931]

When Lewis and Clark explored down the Columbia River in 1805 they found a passageway from the great interior plains of comparative simplicity, with a few sections of rapids and narrows which required portage of their canoes and supplies. By a water-grade route they made their way through a mountain barrier which averages four to eight thousand feet in height, with peaks within 25 miles to the northward and southward rising to eleven and twelve thousand feet. The immediate slopes of this great gorge tower three and four thousand feet directly from the water's edge. While the river itself winds about to some extent, the general contour of the gorge is a gentle curve of 50 to 60 miles in length, the river running a little north of west from its eastern entrance, westward in the deepest section of the cut, and then slightly south of west into the open country of the north-south valley west of the Cascades.

The airplane finds here an easy passageway at normal flying levels through a mountain which at any other point north or south would require an ascent to at least four or five thousand feet to clear the lowest passes in safety. This latest mode of transportation has made possible and necessary the first intensive study of the meteorology of this important and extremely interesting stretch of territory.

Something should be said of the general climatic characteristics of the States of Oregon and Washington to bring out more clearly the marked contrasts which exist east and west of this narrow mountain chain. The coast range and western valley slopes are recipients of an abundant rainfall during the fall, winter, and spring months, averaging 40 to 80 inches a year, while immediately east of the mountains the rainfall averages less than 15 inches annually. Seasonal ranges in temperature west of the mountains are comparatively small, the winters being considerably warmer than is normal for the latitude and the summers cooler, while the interior sections have cold winters and warm summers.

Since there is a mountain barrier between these areas of marked climatic differences their proximity seems only natural, but when one considers a gigantic sea-level cut through this barrier the character of the weather which prevails within it can be better understood.

Geologically this gorge is unique and climatically also it must closely approach that distinction. From a place in the western portion where the annual rainfall amounts to 78½ inches at the river level, the precipitation falls off so markedly with progress eastward that at a point only 18 miles away it is only 34 inches, another 18 miles divides that figure in two, while still farther eastward we find a normal rainfall of only 8 inches.

In October, 1929, a series of four airway stations of the Weather Bureau was opened through the gorge. These are: Crown Point, 24 miles from Portland; Cascade Locks, 45 miles; Hood River, 65 miles; and The Dalles, about 90 miles. During the first four months, or the winter of 1929-30, these stations were not equipped with instruments, but in February, 1930 3-cup anemometers, wind vanes, thermometers, and barometers were supplied to each. January, 1930, had been a remarkable month in the gorge, easterly winds and gales were almost constant, temperatures low, snows deep, and the month, generally, one of the stormiest and coldest in many years. During this period all the winds were estimated by the observers and it is now interesting to note that they never estimated current velocities to be over 50 miles an hour, while it is likely that winds of hurricane strength prevailed over the western portion. The strongest evidence of this is the fact that on the night of January 16-17, a Richfield beacon tower was bent and twisted to the ground by the force of the gale at Crown Point. Since the records of the winter 1930-31 have been compiled it is not difficult to realize that the total wind movement at Crown Point during that month would have approximated 25,000 miles, or an average velocity of 34 miles per hour.

Crown Point is one of the most exposed points along the entire western gorge. It juts out from the south wall at about 700 feet above the river and is very steep. The contour of the rocky formation is such that east and northeast winds are caught and forced upward over the summit, thereby accelerating the true velocity of the wind down the gorge and producing a gusty condition. The extent of this exaggerated condition is not definitely known since no records of wind velocity are available at any other point in the vicinity. At Cascade Locks, 20 miles eastward, the exposure was not entirely satisfactory and no continuous record was made. (Note.—The anemometer, recently removed to an excellent exposure on a rocky promintory in the center of the gorge, now indicates velocities equalling or exceeding those of Crown Point.)

The site at Crown Point was selected for a station because it commands a better view of a greater portion of the gorge than is obtainable from any other point and also because night and day service could be obtained at this place on call. The anemometer was exposed on a 12-foot support on the roof of a 1-story structure directly on the highway, so situated that the exposure eastward into the gorge is excellent. To the north the exposure is good, but due to the fact that the gorge runs east and west, cross winds are uncommon. Westward there is a slight obstruction in the form of some low trees across the highway, but the contour of the point in that direction is such as to ward off westerly winds which seldom exceed gentle to moderate velocities. Southeast, south, and southwest the exposure is unfavorable due to the hills which slope away from the crest of the point. Southwest winds occasionally reach moderate force during rainy periods when strong southerly winds prevail overhead and in the valleys to the west, but a wind velocity of 20 miles or more per hour has not been observed at Crown Point from any direction except east or northeast. On October 21, 1930, a single register for recording wind movement was installed and a continuous record commenced.

The only other records of continuous wind movement in the vicinity are those made at the regular Weather Bureau office in the customhouse in Portland, but the exposure is not satisfactory in all directions and does not represent a true picture of winds in the Portland area. The airport exposure is more satisfactory, there being no obstructions in the form of high buildings. It is low, however, when compared with surrounding hills and bluffs which are some distance from the instrument. Continuous wind movement was not available at this point but by making dial readings at midnight and using the daily total movement in connection with hourly current

velocities a very satisfactory record of total movement was obtained which represents more nearly the average conditions in the immediate Willamette Valley than does the customhouse record. Finally, dial readings were commenced on the 3-cup anemometer exposed on the summit of Council Crest in Portland. This exposure is without parallel in the Pacific Northwest, being 1,200 feet above the Willamette River and 88 feet above ground at the summit. Access to this point by automobile is fairly easy and dial readings were made every four or five days. The record obtained, however, is only for total wind movement but it represents a record of unobstructed flow of wind from all directions above the Portland area.

November, 1930, was the first complete month of record at these points and the following is a table of the wind data:

	Total	Average	Prevailing direction	Maximum velocity and direction
	Miles	*M. p. h.*		
Crown Point	12,580	17.5	NE	70 NE.
Council Crest	10,711	14.9	NE	
Portland Airport	4,496	6.2	SE	
Customhouse	3,481	4.8	SE	20 E.

From the above table it can be seen that Crown Point's total is 3.6 times that of the customhouse, 2.8 times that of the airport, but only 1.1 times that of Council Crest. During this month, the wind at Crown Point blew from the northeast 37 per cent of the time and 71 per cent of the total mileage, while at the customhouse the wind blew from the northeast only 4 per cent of the time and 3 per cent of the total mileage. Southeast was the prevailing direction in the city, the customhouse showing 31 per cent of the time and 30 per cent of the mileage from that direction, the airport 32 per cent of the time and 40 per cent of the mileage. This is the direction which occurs at these two exposures most of the time that strong northeast and east winds prevail at Crown Point. Another very interesting feature of the Crown Point wind during November is that the northeast wind averaged 33.2 miles per hour, the east wind 14.1, while no other direction gave over 6.5. The most remarkable period was from the 22d to the 26th, inclusive, when the wind blew from the northeast every hour of the 120 of the period and averaged 40.1 miles per hour! Equally remarkable is the record from the 21st to the 30th, inclusive, when the wind averaged 33.6 miles per hour and blew from the northeast or east every one of the 240 hours. At the customhouse during the former period the wind averaged 5.6 miles per hour, and during the 10-day period, 5.1 miles, the airport averaging slightly higher than the customhouse. These differences are surprising when one considers that there is no marked barrier in the way of hills between Crown Point and downtown Portland.

November 23d was the windiest day at Crown Point, there being a total movement of 1,278 miles that day, an average of 53.2 miles per hour. The writer had the pleasure of being at the Point during a portion of the day, but not during the time of the maximum wind, which occurred during the morning. Observing the clock closely and counting the buzzes on the wind indicator during some of the heavier gusts, an extreme velocity of 120 miles an hour was noted. The tops of several automobiles were wrecked as they rounded the Point; one woman was thrown to the pavement by the gale and rolled against a stone abutment, suffering injuries which required hospital treatment.

The greatest total movements were recorded during December, 1930, but no unusually high maxima occurred. The following table is for December:

	Total	Average	Prevailing direction	Maximum velocity and direction
	Miles	*M. p. h.*		
Crown Point	17,135	23.0	NE	60 NE.
Council Crest	12,849	17.3	NE	
Portland Airport	5,520	7.4	SE	
Customhouse	4,071	5.5	E	20 E.

The total movement at Crown Point is unusually high, and an inspection of the total movements at regular Weather Bureau stations since the installation of 3-cup anemometers in January, 1928, reveals that it has been exceeded at only two, namely, by 4 miles at Buffalo during January, 1928, and at Tatoosh Island, Wash., during January, 1930, when a total of 17,947 miles was recorded. It is interesting to note that during December, 1930, the total movement at Tatoosh was only 12,718 miles, or 74 per cent of that at Crown Point. The wind movement at Crown Point during the month was over four times that recorded at the customhouse, over three times that at the airport, and 1.3 times that of Council Crest; 96 per cent of the Crown Point total movement was from the northeast or east, while it blew 71 per cent of the time from those directions. The northeast wind averaged 33.8 miles per hour, the east wind 15.6 miles per hour, but winds from other directions averaged only 6.5 miles per hour or less. In Portland the northeast wind as usual was negligible, while the southeast wind at the airport blew 54 per cent of the time, 68 per cent of the total mileage, and averaged 9.5 miles per hour. At the customhouse, east was the prevalent wind, blowing 34 per cent of the time, 49 per cent of the mileage, and averaging 7.7 miles per hour. The difference between the effects of these latter two exposures on east and southeast winds is almost wholly of topographical origin.

During January, 1931, large total movements were registered at the Point and at Council Crest, shown with the airport and customhouse figures in the following table:

	Total	Average	Prevailing direction	Maximum velocity and direction
	Miles	*M. p. h.*		
Crown Point	13,597	18.3	NE	54 NE.
Council Crest	12,530	16.8	SW	
Portland Aircraft	5,686	7.6	SE	
Customhouse	3,883	5.2	SE	30 S.

Comparisons during this month show approximately the same differences as during the two preceeding months, except that Council Crest's total approaches Crown Point's, due to the fact that southerly winds were more frequent over Portland than earlier in the winter.

February, 1931, is somewhat more striking in that the wind at Council Crest exceeds that at Crown Point for the first month since the study was commenced. The values for this month are shown in the table following.

	Total	Average	Prevailing direction	Maximum velocity and direction
	Miles	*M. p. h.*		
Crown Point	10, 496	15.6	NE	54 NE.
Council Crest	10, 585	15.8	NE	
Portland Airport	4, 711	7.0	SE	
Customhouse	3, 560	5.3	E	24 SW.

Due to the shortness of the month, total movements are proportionately lower, but Council Crest exceeds Crown Point in total movement by approximately 100 miles.

In the following table a brief summary of the four months, November, 1930–February, 1931, inclusive, is presented:

	Total	Average	Prevailing direction	Maximum velocity and direction
	Miles	*M. p. h.*		
Crown Point	53, 808	18.7	NE	70 NE.
Council Crest	46, 675	16.2	NE	
Portland Airport	20, 413	7.0	SE	
Customhouse	14, 995	5.2	SE	30 S.

From this it can be seen that Crown Point's total was approximately 3.6 times that at the customhouse, about 2.6 times that at the airport, but only 1.2 times that of Council Crest. However, when one considers that almost the entire mileage at Crown Point was from only two directions, viz., northeast and east, compared with free wind movement from all points at Council Crest, the difference is even more remarkable.

The causes of the easterly gales are interesting and as would be expected are due principally to the fact that during the winter time higher pressure prevails over the continent and lower pressure over the sea. The Cascades form a natural barrier between these pressure differences and steep gradients occasionally occur along the range, It is at these times, of course, that winds at Crown Point are strongest, slackening as the gradient lessens, and disappearing almost entirely when the pressure distribution is reversed. However, other important factors contribute to the strength of the gales, principally temperature. Colder weather accompanies high pressure east of the mountains, while to the westward warm weather with southeast or southerly winds may prevail and this temperature gradient is frequently very strong over the mountains, while the pressure gradient may not be unusual. Strong winds are experienced under such conditions. With the movement inland of a low-pressure area in British Columbia a change of the pressure gradient occurs. Often the gradient over the range is reversed in a comparatively short period. At these times, a flow of colder air from the interior obtains and occasionally lasts for several hours before finally being overcome by the more powerful pressure differences. This change was observed frequently during the winter of 1930–31 and on a few occasions caused glaze deposits in the vicinity of the Point when subfreezing temperature prevailed in the easterly winds from the interior while westward and aloft relatively warm weather accompanied by rain was occurring.

The return of the easterly winds was always a slow and gradual process attending the passage of the oceanic high pressure areas inland over the Cascades, and during such times the temperature gradients were unimportant. The wind did not shift to easterly until the center of the high pressure definitely passed over the range, after which the increase in velocity was slow and steady. However, if a strong continental high had moved southward into the interior, the shift and increase in wind might have been abrupt and accompanied by a cold wave. No such cases occurred during the winter, but during the great wind and dust storm of April 21–24, 1931, a somewhat similar case did occur and the wind at Crown Point rose abruptly from 20 to 50 miles per hour with the arrival of the wind shift. (NOTE.—MONTHLY WEATHER REVIEW, May, 1931, p. 195.)

Conditions of pressure and temperature during the winter 1930-31 were decidedly abnormal, especially as regards the persistence of the pleateau high over Idaho and eastern Oregon. During a normal winter such remarkably steady and prolonged gales would not be experienced, but quite likely some higher maximum velocities would occur. An ideal type for winds of hurricane strength would be a strong high moving southward into eastern Washington and Oregon from Canada and an oceanic low-pressure area off the central Oregon coast. Just such a pressure distribution occurred on the night of January 16–17th, 1930, when the destruction of the steel tower, described previously, took place.

Results of the easterly gales in the Columbia River gorge are many and varied but space does not permit their being discussed in detail. In general they are responsible for more uniformly low daytime temperatures at Portland and higher night temperatures during clear, winter weather, while northward and southward away from the effects of the gorge winds much larger ranges in temperature occur. Perhaps one of the most beneficial effects of the gorge winds in the Portland area is their reduction in the hours of ground fog as compared with other sections any distance north or south, where marked temperature inversions occur during clear, calm nights. The motion of the air in the Portland area and its relative dryness are the principal causes for lack of fog. While it must be admitted that the winter of 1930–31 was one of unusual fogginess in the valleys between the Cascades and the Coast Range, due to persistence of high pressure over the interior of the Northwestern States and resulting clear skies, the following table has been prepared to show the number of hours during the four month's period, November to February, with moderate or dense fog (visibility three-fourths mile or less):

	Number hours with moderate or dense fog				
	November	December	January	February	Total
Portland	96	57	47	29	229
Salem	162	180	173	65	580
Roseburg	188	135	141	80	544
Seattle	185	92	90	42	409

Salem, Roseburg, and Seattle were selected to make the comparison because they are all located in the valley country between the Cascades and Coast Range, although local topography is considerably varied, and because hourly records of fog were available.

During each of the months Portland ranked lowest in the number of hours of fog, the difference being especially marked when compared with the record at Salem (50 miles south of Portland). During December and January, Salem had over three times as many hours with fog as Portland. On no single day during the period did fog persist at Portland throughout the daylight hours, while at Seattle this condition occurred on three days, and at Salem on four days.

In reviewing the record of the easterly gales during the winter of 1930–31 only one phase of the weather in this most unique section has been described.

FREE-AIR WINDS AT SAN JUAN, P. R.

By C. L. RAY

[Weather Bureau Office, San Juan, P. R., October 13, 1931]

More than 500 pilot-balloon observations at San Juan have reached an altitude of 10 kilometers or more up to the present time (October, 1931). Pilot-balloon work was begun there in the summer of 1920, and was at first confined to the summer and autumn months, but from May, 1926 records have been obtained daily throughout the year, except when they were interrupted by inclement weather. In February, 1931, an evening observation was added to the daily program, necessarily limited, however, in altitude owing to fading, or extinguishing, of the small candle light. The number of all observations up to October, 1931, amounts to more than 3,500. On the average between 15 and 20 per cent of the daylight flights attained an altitude of 10 kilometers or higher. Although the visibility seldom is better than six to seven (fair to good), long observations are made possible by the reverse or westerly current above the "trades."

At San Juan the record of long runs is due, in part, to the unremitting interest of Dr. O. L. Fassig under whose direction this work was started in 1920.

The following summation of the seasonal averages at the several levels is of interest particularly as it relates to the winds in the upper layers of the troposphere and the lower stratosphere. With this in mind, the averages have been based on the flights which attained the 10-kilometer level or higher. A paper by Doctor Fassig in the MONTHLY WEATHER REVIEW, vol. 52, January, 1924, covers some of the more interesting records made up to that time. The following data include also such of those earlier observations as pertain to the extreme altitudes. Owing to the greater number of years in which observations were made in the summer and autumn periods, larger proportions of the data refer to those seasons than to the others. It is believed, however, that there are sufficiently numerous observations to fairly represent each of the four seasons. This grouping and also that by levels are given in Table 1.[1]

TABLE 1.—*Number of observations by seasons and different levels, San Juan, P. R.*

Observations:	
Spring	62
Summer	167
Autumn	234
Winter	44
Annual	507
Surface to—	
10 kilometers	507
11 kilometers	378
12 kilometers	271
13 kilometers	172
14 kilometers	90
15 kilometers	54
16 kilometers	25
17 kilometers	17
18 kilometers	11
19 kilometers	9
20 kilometers	8
21 kilometers	6
22 kilometers	4
23 kilometers	2
24 kilometers	2
25–33 kilometers	1

[1] The results for heights above 15 kilometers must be accepted with the reservation that they are based on single theodolite observations and therefore on an assumed ascensional rate for which sufficient confirmation data by two theodolites have not yet been obtained.

Throughout the year the surface winds frequently are from some easterly point. An east component occurred in 64 per cent of all such winds under consideration. However, the chief surface component, found in 85 per cent of the cases, is southerly, particularly in the early morning hours. This off-shore wind shifts to more easterly by 9 or 10 a. m. Table 2 gives the percentage of annual and seasonal frequencies of wind directions at the surface and in the upper levels to 10 kilometers, while Figure 1 shows the summer and winter directions percentages at the surface and at the 2, 6, and 10 kilometer levels. It will be noted that the prevailing component is easterly up to 4 kilometers in all seasons and to 6 kilometers in the summer period, and westerly at the 8 and 10 kilometer levels.

TABLE 2.—*Percentage frequency of winds observed from various directions at San Juan, P. R.*

Altitude (meters)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
SPRING																
Surface	0	0	0	10	15	15	25	20	11	2	2	0	0	0	0	0
1,000	0	2	0	6	36	38	18	0	0	0	0	0	0	0	0	0
2,000	0	3	0	20	28	25	12	5	3	1	0	1	1	0	0	1
4,000	5	7	7	12	25	7	3	2	6	1	8	3	3	5	3	3
6,000	12	12	3	12	3	0	3	0	0	2	8	14	8	14	6	3
8,000	2	6	5	0	2	0	0	0	0	0	3	20	8	28	16	10
10,000	3	1	0	0	0	0	0	0	0	1	1	3	33	35	13	10
SUMMER																
Surface	0	0	0	6	16	18	26	15	12	3	2	1	1	0	0	0
1,000	1	0	0	2	40	39	14	2	1	1	0	0	0	0	0	0
2,000	0	1	1	11	28	36	15	3	2	1	0	1	0	0	0	1
4,000	2	5	10	15	17	16	14	7	4	3	3	2	0	0	1	1
6,000	6	5	10	13	11	9	10	4	4	3	5	5	5	4	3	3
8,000	7	3	5	5	6	3	4	2	7	5	5	12	11	7	11	7
10,000	6	6	9	5	3	3	2	3	3	4	7	12	16	11	5	5
AUTUMN																
Surface	0	0	1	1	2	5	16	26	30	15	3	1	0	0	0	0
1,000	0	1	4	11	22	30	16	5	5	2	0	1	1	1	1	0
2,000	2	4	4	9	23	20	14	7	3	3	2	2	2	2	2	1
4,000	5	4	10	11	9	11	5	6	9	6	7	4	6	1	3	3
6,000	6	8	7	6	5	6	5	5	8	9	6	7	6	7	3	6
8,000	10	8	7	5	4	3	3	3	4	6	9	8	11	8	4	7
10,000	9	8	5	3	3	3	3	2	2	4	5	6	12	13	9	13
WINTER																
Surface	0	0	0	2	0	7	16	27	30	11	7	0	0	0	0	0
1,000	2	0	5	15	48	18	5	5	0	0	0	2	0	0	0	0
2,000	2	7	2	20	25	23	9	0	0	0	0	5	2	5	0	0
4,000	0	7	4	16	16	14	2	2	0	7	5	2	11	0	9	5
6,000	2	11	11	0	5	11	5	2	0	7	2	11	16	5	5	7
8,000	2	7	7	0	2	0	6	0	0	5	9	14	25	5	7	11
10,000	2	0	0	4	0	0	0	0	0	5	0	14	27	23	14	11
ANNUAL																
Surface	0	0	0	4	8	11	20	22	22	9	3	1	0	0	0	0
1,000	1	1	2	8	32	33	15	3	3	1	0	1	0	0	0	0
2,000	1	3	2	12	26	26	14	5	2	2	1	2	1	1	1	1
4,000	4	5	9	13	13	13	7	6	6	5	5	3	4	1	3	3
6,000	6	6	8	9	7	7	6	4	5	6	6	8	7	6	4	5
8,000	7	6	6	4	4	2	5	2	4	5	7	11	11	10	8	8
10,000	7	5	5	3	2	2	2	2	2	4	5	9	17	16	9	10

Table 3 shows the frequencies of different wind components at and above the 10-kilometer level. North and west components persist up to 15 kilometers, then south

and west or south and east to 16 or 17 kilometers, and finally, north and east components at the 18 to 22 kilometer levels. Two flights were followed to a height of 24 kilometers and one to 33 kilometers. The latter is discussed in detail in the MONTHLY WEATHER REVIEW, January, 1924, referred to above.

TABLE 3.—*Percentage frequency of wind components in levels at and above 10 kilometers*

Direction between—	Kilometers												
	10	11	12	13	14	15	16	17	18	19	20	21	22
SSW. and NNW. (W.)	70	69	65	70	60	69	52	29	27	0	25	33	22
SSE. and NNE. (E.)	21	22	24	20	31	24	36	41	73	78	62	67	75
ESE. and WSW. (S.)	26	22	27	28	34	35	56	53	36	11	38	33	0
WNW. and ENE. (N.)	55	63	56	53	54	56	28	29	45	44	50	50	75
No. of observations	507	398	271	172	91	54	25	17	11	9	8	6	4

NOTE.—2 observations to 24 kilometers with ENE. to E. and ESE. to WNW. at 23 and 24 kilometers respectively; 1 observation to 33 kilometers with change in direction from 25 kilometers to 33 kilometers, in the following shift—W. to SE. to S. to WNW. to SW. at 33 kilometers, velocity 3 to 15 meters per second.

Owing to the small number of observations at the higher levels their averages are somewhat unreliable. There seems, however, to be a well-defined north by westerly current from the 7-kilometer level to the fifteenth, and a fairly continuous east component in the winds above the 17-kilometer level.

TABLE 4.—*Mean free-air winds at San Juan, P. R.*

[Velocity in meters per second]

Altitude (meters)	Spring		Summer		Autumn		Winter		Annual	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	S-48-E	3.0	S-47-E	2.3	S-15-E	1.9	S-14-E	2.2	S-29-E	2.2
500	S-77-E	8.7	S-75-E	8.2	S-70-E	5.9	S-87-E	7.6	S-74-E	7.1
1,000	S-75-E	9.2	S-72-E	8.7	S-70-E	5.9	S-82-E	7.9	S-72-E	7.4
2,000	S-79-E	6.1	S-74-E	7.4	S-76-E	5.0	N-87-E	6.0	S-77-E	6.0
3,000	N-77-E	5.5	S-73-E	6.3	S-68-E	4.4	N-77-E	5.1	S-76-E	5.2
4,000	N-82-E	4.9	S-81-E	5.3	S-76-E	4.1	N-74-E	5.0	S-81-E	4.7
5,000	N-40-W	4.9	E	5.1	S-49-E	4.8	N-14-E	5.8	S-83-E	5.2
6,000	N-43-W	6.6	N-83-E	4.8	S-15-W	4.8	N-40-W	7.2	N-53-E	5.2
7,000	N-53-W	8.5	N-12-W	5.2	N-73-W	5.5	N-58-W	9.0	N-47-W	6.0
8,000	N-59-W	10.9	N-58-W	6.1	N-56-W	6.6	N-77-W	9.4	N-60-W	7.2
9,000	N-66-W	14.2	N-67-W	6.3	N-51-W	7.3	N-74-W	13.1	N-62-W	8.3
10,000	N-70-W	18.0	N-69-W	8.1	N-43-W	9.5	N-73-W	17.0	N-60-W	10.7
11,000	N-69-W	18.4	N-65-W	9.2	N-50-W	10.7	N-74-W	21.9	N-60-W	11.5
12,000	N-71-W	18.1	N-67-W	9.5	N-44-W	11.4	N-73-W	21.6	N-58-W	12.0
13,000	N-72-W	19.4	N-69-W	9.8	N-61-W	12.2	N-68-W	20.3	N-65-W	12.5
14,000	N-62-W	21.0	N-87-W	10.5	N-50-W	11.5	N-20-W	22.0	N-65-W	13.0
15,000	N-68-W	20.8	N-49-W	13.0	N-68-W	12.8	N-19-W	22.0	N-59-W	14.9

Table 4 gives the mean free-air winds and Table 5 the free-air resultant winds, by seasons and for the year from the surface to the 15-kilometer level.[2] Figure 2 shows the mean free-air wind directions and velocities. Here we note that in the spring the wind is easterly below the 4-kilometer level and westerly above; in the summer, easterly up to the 6-kilometer level but westerly at and beyond 7 kilometers; in autumn and winter, easterly up to 5 kilometers and westerly at and above 6 kilometers. In the free-air resultant winds no marked difference in direction occurs, compared with that of the average winds, but there is some reduction in velocity which is particularly evident in the summer and autumn months when the persistence of easterly winds to higher levels tends to lower the values of the resultant westerly speeds.

[2] In obtaining "mean" or "average" winds the directions and velocities are considered independently, whereas, "resultant" winds are determined by first resolving each observation into its north and west components and then adding these vectorially.

TABLE 5.—*Free-air resultant winds at San Juan, P. R.*

[Velocity in meters per second]

Altitude (meters)	Spring		Summer		Autumn		Winter		Annual	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	S-73-E	2.3	S-59-E	1.9	S-19-E	1.5	S-22-E	1.6	S-42-E	1.8
500	S-79-E	8.3	S-73-E	7.7	S-73-E	5.0	S-88-E	7.0	S-76-E	6.5
1,000	S-75-E	8.2	S-77-E	8.0	S-72-E	4.9	S-78-E	7.3	S-77-E	6.7
2,000	S-82-E	5.1	S-75-E	6.7	S-75-E	3.5	N-88-E	4.5	S-77-E	4.8
3,000	N-89-E	3.5	S-82-E	3.4	S-73-E	2.0	N-73-E	2.8	S-82-E	2.7
4,000	N-85-E	2.2	S-80-E	3.5	S-71-E	1.4	N-67-E	1.7	S-82-E	2.1
5,000	N- 5-W	0.7	N-88-E	2.7	S-54-E	0.6	N-88-E	0.2	S-88-E	1.2
6,000	N-43-W	2.4	N-84-E	1.4	N-39-W	0.4	N-14-W	0.8	N-31-E	0.6
7,000	N-55-W	5.0	N-34-W	0.6	N-34-W	0.9	N-70-W	3.4	N-51-W	1.2
8,000	N-64-W	8.8	N-52-W	2.0	N-50-W	1.6	N-81-W	5.0	N-61-W	2.7
9,000	N-66-W	11.5	N-69-W	2.2	N-46-W	2.9	N-77-W	9.0	N-62-W	4.0
10,000	N-74-W	16.7	N-75-W	3.2	N-39-W	4.5	N-76-W	14.6	N-64-W	6.0
11,000	N-72-W	16.8	N-68-W	4.0	N-50-W	5.4	N-76-W	19.7	N-76-W	6.0
12,000	N-72-W	16.9	N-64-W	3.8	N-47-W	5.9	N-80-W	20.0	N-61-W	6.7
13,000	N-72-W	19.4	N-80-W	4.4	N-59-W	6.4	N-75-W	16.8	N-68-W	7.1
14,000	N-57-W	16.4	N-86-W	4.1	N-55-W	3.6	N-17-W	18.7	N-65-W	5.8
15,000	N-68-W	20.8	N-61-W	8.1	N-60-W	4.4	N-17-W	16.9	N-52-W	7.8

The proportion of clockwise to counter-clockwise east-to-west shifts, which generally occur near the 6-kilometer level, was tabulated for each season. An average of 65 per cent turn counter-clockwise in the winter and spring months, and 54 per cent during summer. In the autumn, when the southeast trades are deeper, 52 per cent of the shifts are clockwise.

TABLE 6.—*Free-air resultant winds at San Juan, P. R. (1926–1931)*

[Velocities in meters per second]

Altitude (meters)	Spring		Summer		Autumn		Winter		Annual		Observations
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	
Surface	S-83-E	2.5	S-82-E	2.9	S-65-E	1.6	N-86-E	2.7	S-82-E	2.5	1,725
500	S-81-E	7.9	S-83-E	8.6	S-86-E	7.6	N-82-E	7.6	S-87-E	7.6	1,725
1,000	S-79-E	7.9	S-78-E	9.6	S-83 E	6.7	N-84-E	8.0	S-84-E	8.0	1,709
2,000	S-81-E	5.0	S-78-E	8.6	S-83-E	5.3	N-82-E	6.3	S-84-E	6.1	1,496
4,000	S-7-W	0.2	S-78-E	4.6	S-81-E	2.5	N-66-E	2.6	S-85-E	2.2	985
6,000	N 78-W	4.8	S-76-E	1.7	N-59-E	1.0	N-54-W	2.9	N-59-W	1.3	668
8,000	N-72-W	8.9	N-65-W	1.1	N-15-W	1.8	N-74-W	8.9	N-66-W	4.2	458
10,000	N-65-W	16.8	N-71-W	3.0	N-25-W	5.2	N-71-W	16.4	N-61-W	6.3	305

Table 6 shows the resultant winds based on all the observations obtained from 1926 to October, 1931. From the surface to 1,000 meters the number of observations in this group is approximately 1,700. The number decreases as the higher levels are approached until at 6 kilometers it is only slightly in excess of the number used as the basis for Tables 4 and 5. Differences in the two sets of averages appear inconsiderable and indicate, in the main, only a difference in the wind-shift level. Thus, in Table 5 the first westerly component (annual) appears at the 7-kilometer level, while in Table 6, with a somewhat greater number of observations as a basis, the north-by-west winds occur first at the height of 6 kilometers. Presumably, therefore, the average reversal level for the year over a long period is somewhat under 6 kilometers.

In October, 1931, conditions were favorable for extended upper-air observations as is generally true of the autumn period. An observation of particular interest occurred on October 21, 1931, the horizontal projection of which appears as Figure 3. Conditions on the morning of the flight were normal at the station, barometer 29.97 inches (sea level), temperature 76° F., surface wind from the southeast, velocity 4 m.p.s., and visibility 7

(good). To the north a cyclonic disturbance of moderate development, which had moved up from the western Caribbean between the seventeenth and twentieth, lowest pressure 29.7 inches, was central on the morning

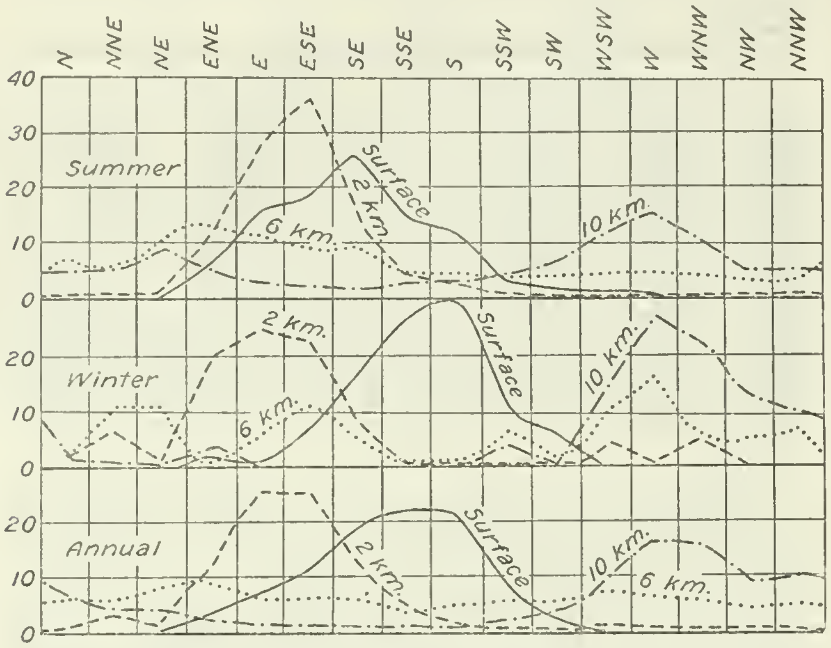

FIGURE 1.—Percentage frequency of winds from different directions at the surface 2, 6, and 10 kilometers, at San Juan, P. R.

of the 21st at latitude 29° N. and longitude 68° W. The balloon was observed to the altitude of 17.9 kilometers. The winds were southeast to south to southwest and west up to 7.6 kilometers; at 8 kilometers they shifted to north and northeast, and were light to 9.5 kilometers, then northwest, west, and southwest to 10.5 kilometers. Between 10.7 and 16.5 kilometers there was an east component—ESE. to SE.—shifting to SSW. at 16.6 kilometers, with a marked increase in velocity to 29.5 m.p.s. from SSW. at the maximum altitude of 17.9 kilometers. The southerly component presumably was due to the barometric depression to the north of the station. Three

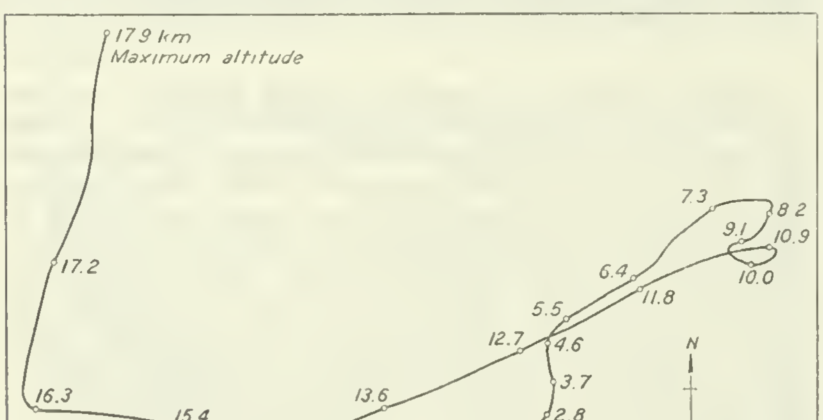

FIGURE 3.—Horizontal trajectory of pilot-balloon flight of October 21, 1931, cyclonic disturbance to the north, central in latitude 29 N., longitude 68 W. (elevation in kilometers and tenths indicated along the curve)

other flights during this same month were observed to elevations of 15 to 17 kilometers, and each showed a northerly component of the wind at its maximum altitude. (The average winds at 17 to 18 kilometers [Table 3] are N. by E.). The pressure in all three instances was generally high throughout the north and middle Atlantic.

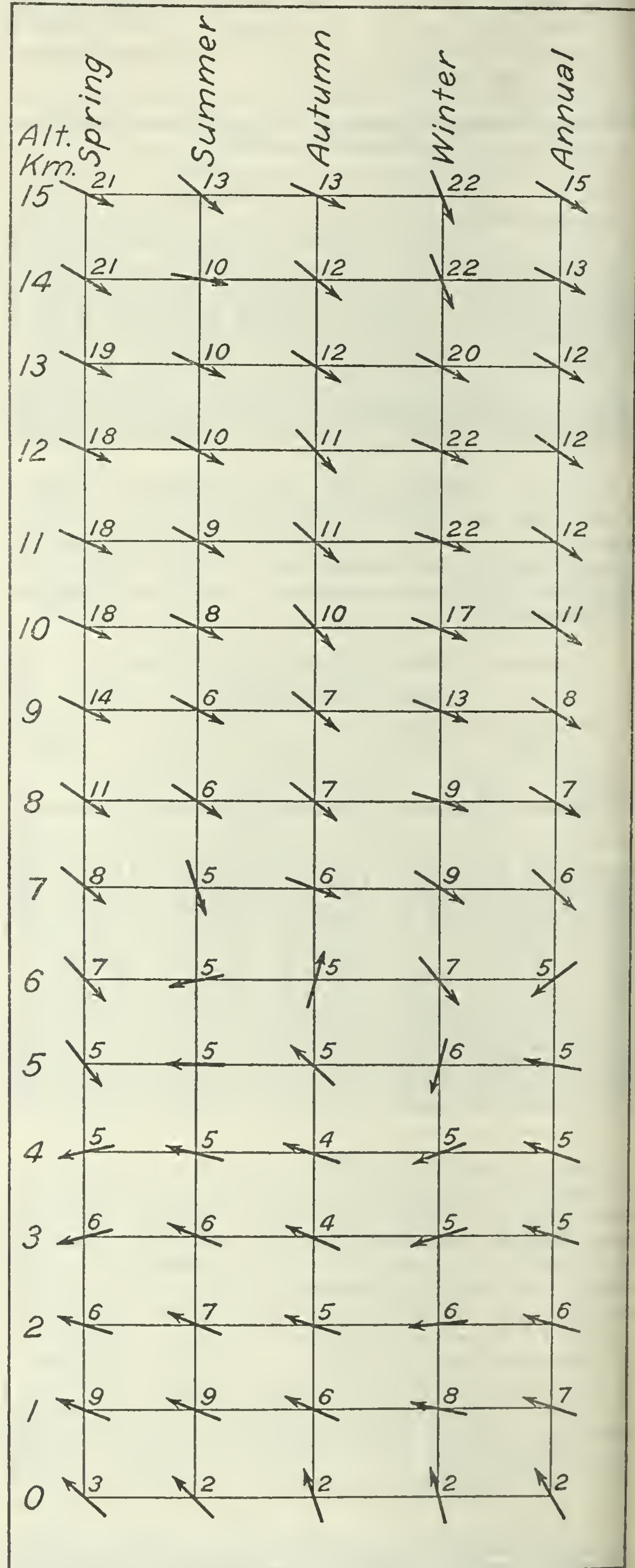

FIGURE 2.—Average free-air winds, direction, and velocities (m.p.s.) at San Juan, P. R.

SOUNDING-BALLOON OBSERVATIONS AT ROYAL CENTER, IND., DURING THE INTERNATIONAL MONTH, SEPTEMBER, 1930

By L. T. SAMUELS

[Weather Bureau, Washington, D. C., July, 1931]

In cooperation with the International Commission for the Exploration of the Upper Atmosphere the Weather Bureau conducted a series of sounding-balloon observations at the Royal Center,[1] Ind., aerological station during the international month, September, 1930. The same general program was followed as at Broken Arrow, Okla., during December, 1929, and the reader is referred to Monthly Weather Review, August, 1931, for further details regarding this. There were 36 balloons released at Royal Center and 34 (94 per cent) of the instruments returned. This is probably the highest percentage ever returned for a complete monthly series in this country.

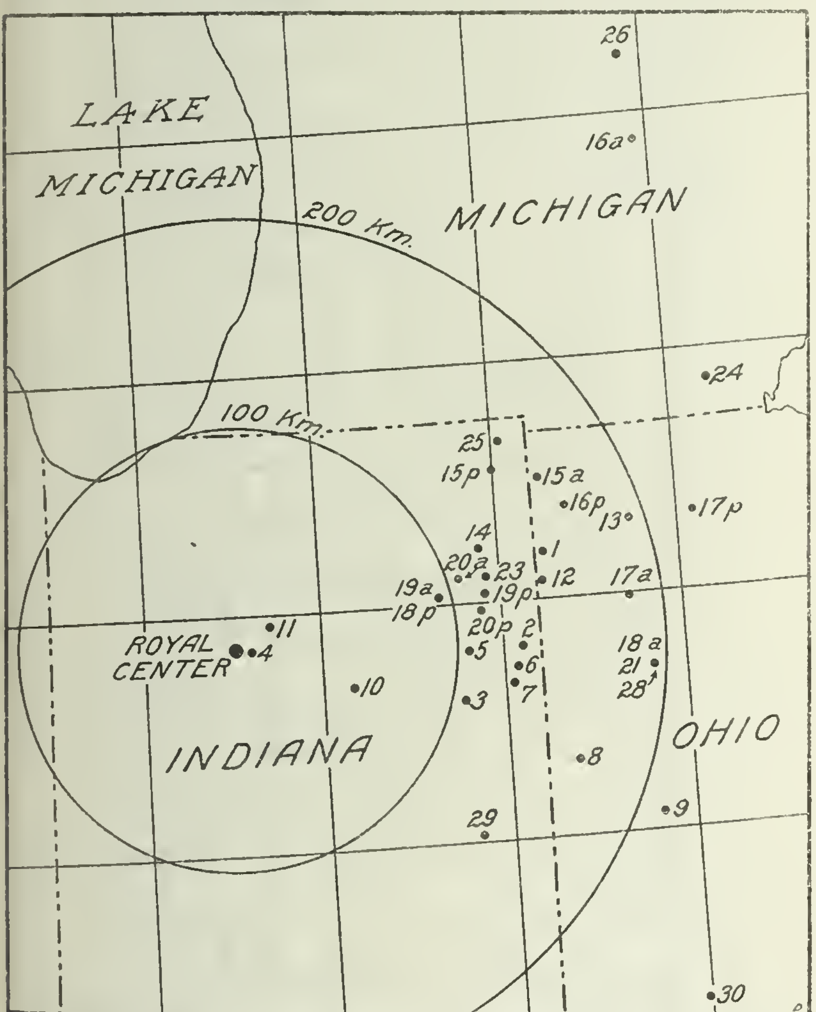

FIGURE 1.—Landing places (with dates of ascent) of meteorographs released from Royal Center, Ind., during September, 1930

The altitudes determined hypsometrically were, in general, slightly higher than those computed trigonometrically from the 2-theodolite observations, the differences averaging less than 5 per cent.

The average maximum altitude reached during the series was 12,122 meters and the extreme maximum altitude reached was 23,846 meters, on the afternoon of the sixteenth.

Following are some of the significant features of the tropopause obtained for the more recent monthly series of sounding balloon observations made in this country. (See Figure 1.)

[1] Lat. 40° 53′ N., long. 86° 29′ W.

	Date	Mean height of tropopause	Mean temperature of tropopause	Maximum height of tropopause observed	Minimum height of tropopause observed	Range in height of tropopause observed
		Meters	° *C.*	*Meters*	*Meters*	*Meters*
Royal Center, Ind.	September, 1930	12, 914	−59.3	14, 615	10, 898	3, 717
Broken Arrow, Okla[1]	December, 1929	10, 083	−54.0	12, 212	7, 728	4, 484
Groesbeck, Tex.[2]	October, 1927	14, 823	−65.5	17, 467	11, 695	5, 772
Royal Center, Ind.[3]	May, 1926	12, 011	−58.4	15, 840	8, 878	6, 962

[1] MONTHLY WEATHER REVIEW, August, 1931, pp. 297–309.
[2] MONTHLY WEATHER REVIEW, June, 1929, pp. 231–246.
[3] MONTHLY WEATHER REVIEW, July, 1927, pp. 293–307.

The mean temperature curve for the month together with the altitude and temperature of the tropopause for the individual observations and the corresponding dates are shown in Figure 2. The maximum monthly average lapse rate and the altitude at which it occurred is given below for the more recent monthly series of sounding-balloon observations in this country.

	Date	Maximum average lapse rate	Altitude interval of occurrence
		° *C/100 m.*	*km.*
Royal Center, Ind.	September, 1930	0.77	9–10
Broken Arrow, Okla[1]	December, 1929	.77	6–7
Groesbeck, Tex.[2]	October, 1927	.79	7–8
Royal Center, Ind.[3]	May, 1926	.71	7–8

[1] MONTHLY WEATHER REVIEW, August, 1931, pp. 297–309.
[2] MONTHLY WEATHER REVIEW, June, 1929, pp. 231–246.
[3] MONTHLY WEATHER REVIEW, July, 1927, pp. 293–307.

In Figure 3 are shown the individual temperature-altitude curves. The surface temperature is indicated at the bottom of each curve and the temperature at the maximum altitude at the top. The wind directions whenever observed are indicated for the standard levels adjacent to the corresponding curves.

In Figure 4 are shown the free-air isotherms for the month with the dates indicated across the top. The temperatures in the upper portion of the troposphere did not fluctuate greatly from day to day. In general, they became higher when the sea-level pressure was low and vice versa, i. e., lower when the sea-level pressure was high.

Attention is invited to the successive increase in height of the tropopause from the afternoon of the sixteenth to the afternoon of the nineteenth as shown in Table 1. As would be expected, the prevailing pressure distribution over this region changed from low to high during this period.

Figure 5 shows the mean wind velocity and direction curves for the month. The mean velocities and mean directions were determined independently of each other. It will be noted that the mean velocity reaches a maximum (38.5 m. p. s.) at 12 kilometers, i. e., just below the mean altitude of the tropopause. Above this elevation the mean wind velocity decreases at practically the same rate it increased in the troposphere.

The mean wind direction veers from southwest near the surface to slightly north of west from 2 kilometers to

10 kilometers where it backs to slightly south of west above.

Figure 6 shows the mean free-air relative humidity for the month. These data, however, must be accepted with reservation above 7 kilometers elevation on account of the uncertainty of hair hygrometers at low temperatures. It is known that the lag of hair hygrometers increases as the temperature falls below $-15°$ C.

In Table 2 are given the tabulated data of the individual ascents. The elevation of the tropopause has been indicated in each case where it was observed.

References to previous sounding-balloon series made in this country may be found in Monthly Weather Review, July, 1927, June, 1929, August, 1931.

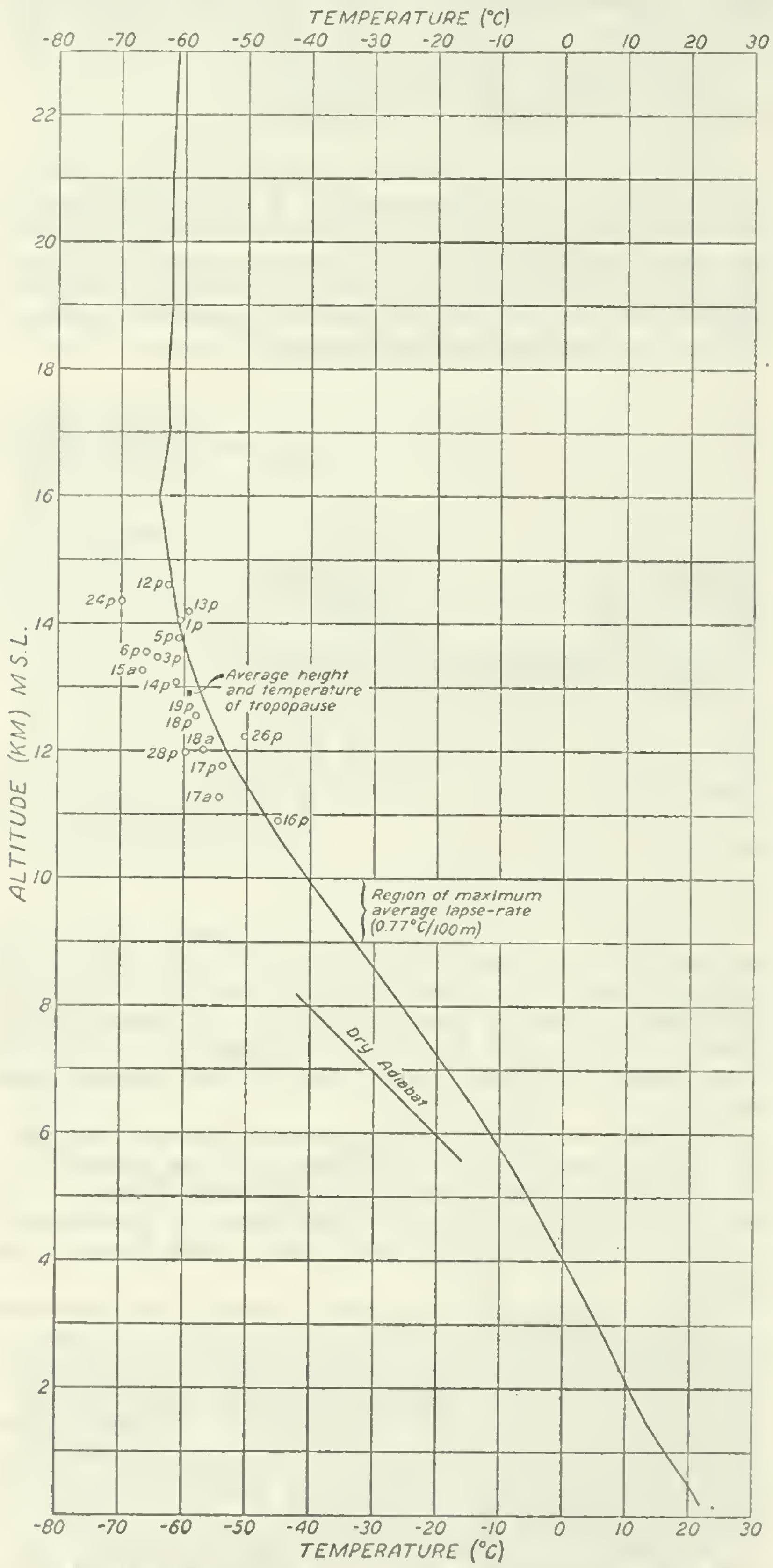

Figure 2.—Mean temperature curve (° C.) for September, 1930, Royal Center, Ind. Circles indicate height and temperature of tropopause with corresponding dates _ _

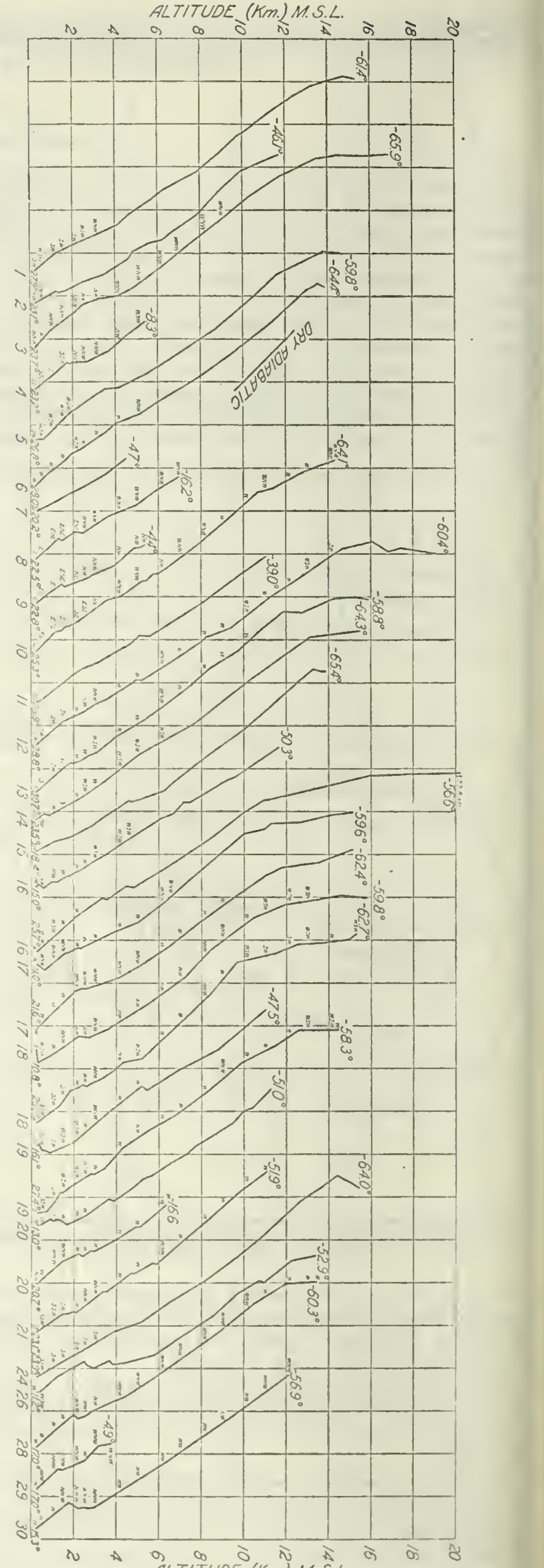

Figure 3.—Temperature-altitude curves for individual observations made at Royal Center, Ind., during September, 1930. Dates indicated below; figures at bottom and at top of curves indicate corresponding temperatures ° C. (Abscissa value of each square represents 20° C.)

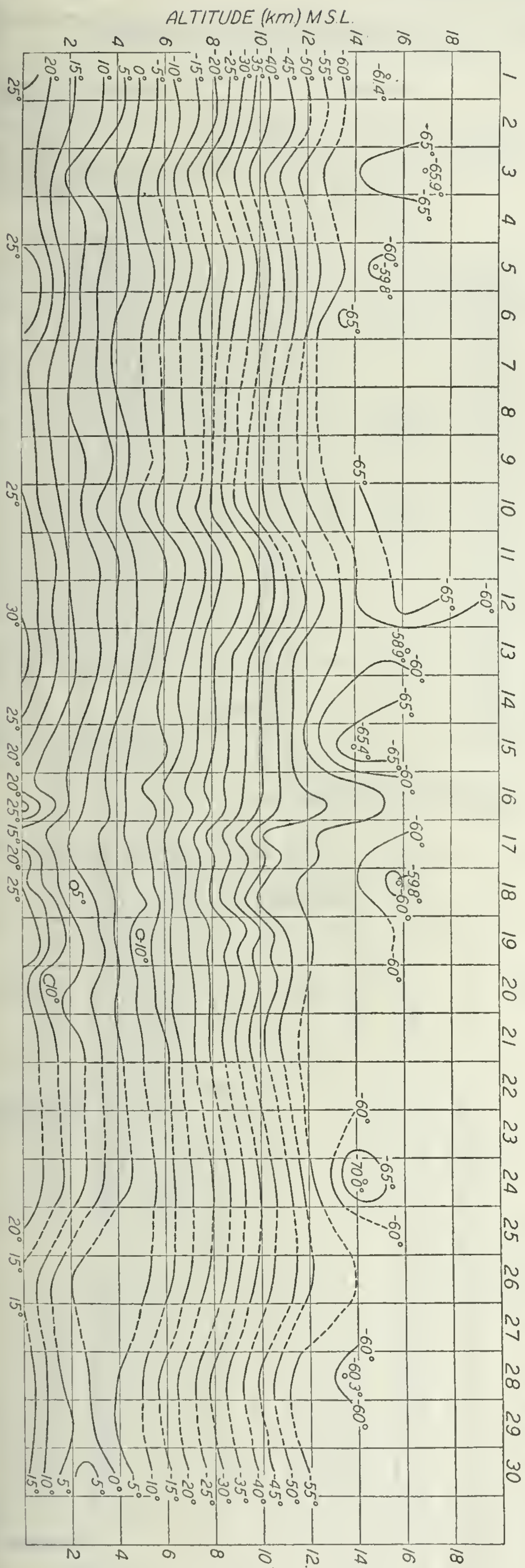

FIGURE 4.—Free-air isotherms (° C.) observed at Royal Center, Ind., during September, 1930. (Broken lines drawn between dates with missing data.)

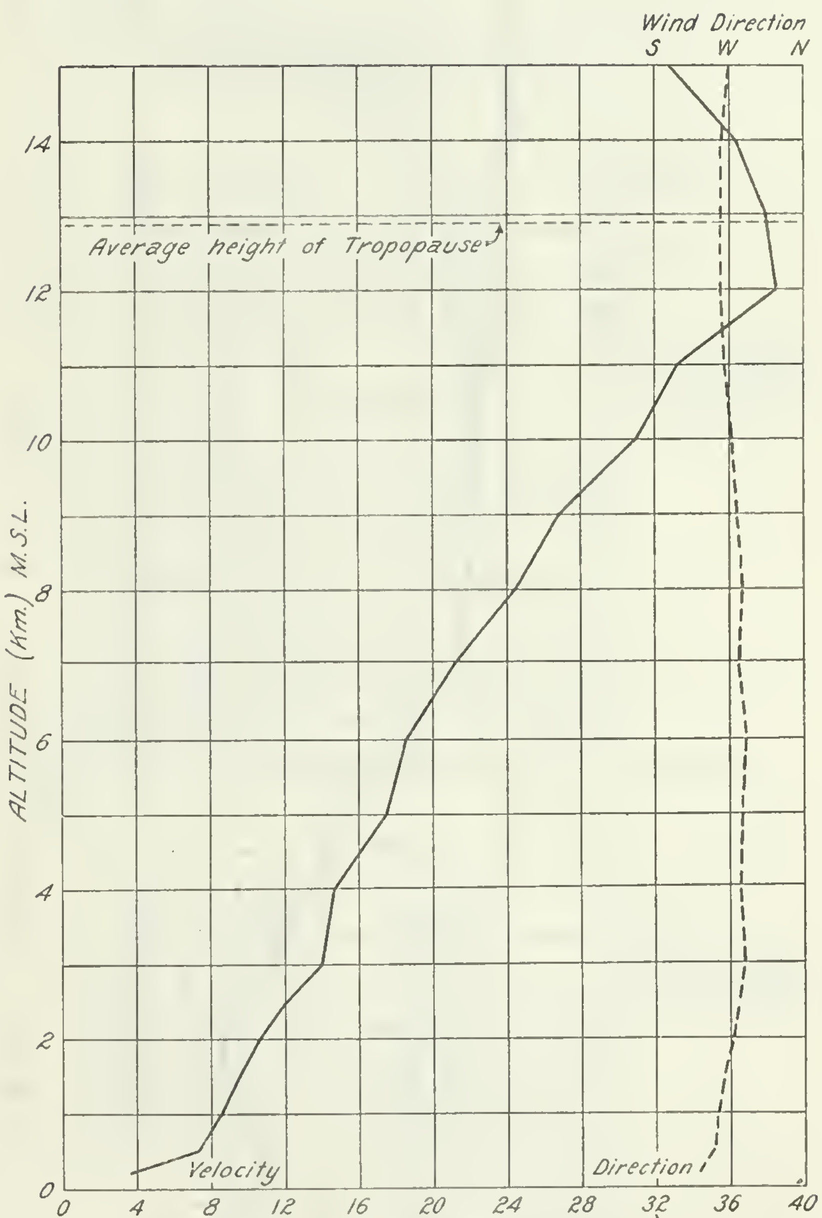

FIGURE 5.—Mean wind velocity (m. p. s.) and direction curves for September, 1930, Royal Center, Ind.

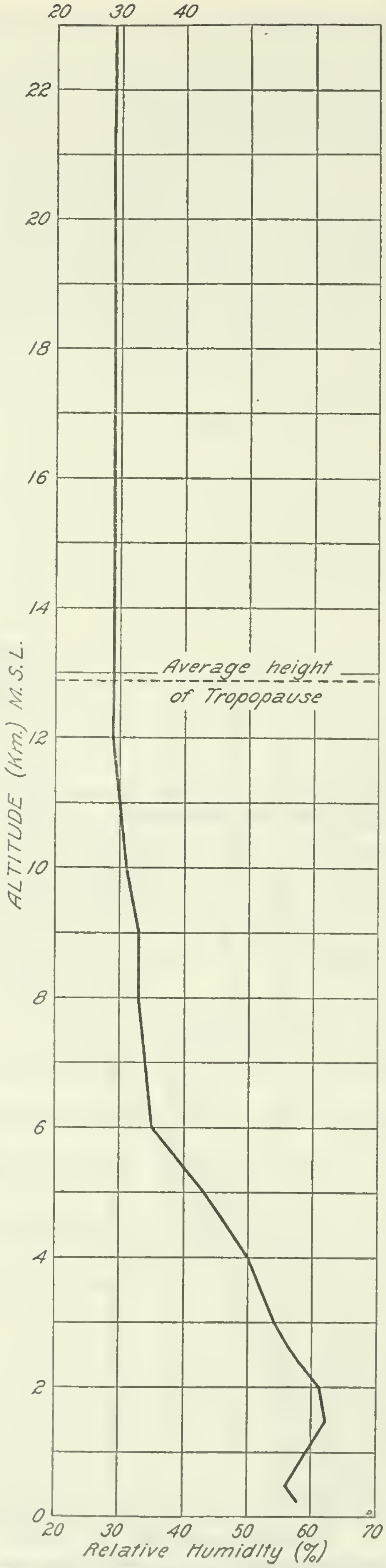

FIGURE 6.—Mean relative humidity curve (per cent) for September, 1930, Royal Center, Ind.

TABLE 1.—*Summary of sounding-balloon observations made at Royal Center, Ind., during September, 1930*

Date	Time of release, 90th Mer.	Stratosphere: Height of base M.S.L.	Stratosphere: Temperature at base	Maximum height reached, M. S. L.	Minimum temperature recorded	Observations: 2-theodolite	Observations: 1-theodolite	Meteorograph found: Distance from station	Meteorograph found: Direction from station
		Meters	*°C.*	*Meters*	*°C.*	*Min.*	*Min.*	*Km.*	
1	4:26 p. m.	14, 035	−60. 8	15, 343	−62. 6	74	24	145	ENE.
2	4:15 p. m.			11, 751	−46. 1	2	2	134	E.
3	4:03 p. m.	13, 449	−64. 1	16, 932	−65. 9	63	75	125	E.
4	4:09 p. m.			5, 422	−8. 3	32	32	7	SE.
5	4:00 p. m.	13, 771	−60. 7	14, 774	−60. 7	7	7	105	E.
6	3:59 p. m.	13, 535	−66. 0	13, 879	−66. 0	24	29	130	E.
7	4:00 p. m.			[1] 4, 498	−57. 3	0	0	125	E.
8	4:00 p. m.			6, 973	−16. 2	59	78	165	ESE.
9	4:09 p. m.			[2] 11, 508	−4. 4	84	96	210	ESE.
10	4:06 p. m.			[2] 15, 453	−64. 1	53	53	70	ESE.
11	4:16 p. m.			11, 048	−39. 0	56	56	20	ENE.
12	4:09 p. m.	14, 615	−62. 5	19, 028	−65. 8	79	111	145	E.
13	4:02 p. m.	14, 183	−59. 2	15, 893	−60. 1	60	70	390	ENE.
14	4:18 p. m.	13, 071	−61. 3	15, 495	−64. 3	17	18	70	ENE.
15	6:16 a. m.	13, 248	−66. 5	13, 888	−66. 5	0	0	155	ENE.
15	4:11 p. m.			[2] 5, 925		22	23	140	NE.
16	6:20 a. m.			11, 675	−50. 3	21	21	310	NE.
16	4:01 p. m.	10, 898	−45. 2	23, 846	−58. 0	6	6	160	ENE.
17	6:26 a. m.	11, 267	−54. 4	15, 148	−59. 6	22	65	170	E.
17	4:13 p. m.	11, 766	−53. 8	15, 141	−62. 4	34	38	225	ENE.
18	6:33 a. m.	12, 024	−56. 9	15, 783	−60. 9	42	105	195	E.
18	4:01 p. m.	12, 534	−58. 1	15, 298	−62. 7	69	72	95	ENE.
19	6:33 a. m.			11, 027	−47. 5	18	74	95	ENE.
19	4:10 p. m.	12, 552	−58. 0	[2] 15, 519	−63. 5	63	66	120	E.
20	6:34 a. m.			11, 271	−51. 0	9	9	105	ENE.
20	4:10 p. m.			[2] 6, 709	−16. 6	40	44	110	E.
21	4:27 p. m.			[2] 11, 057	−51. 9	37	41	195	E.
22	4:00 p. m.			[2] 7, 733		34	41	([3])	
23	4:00 p. m.			[2] 3, 825		15	17	115	ENE.
24	3:58 p. m.	14, 357	−69. 9	15, 461	−69. 9	12	14	250	ENE.
25	3:59 p. m.			[2] 13, 283		64	69	155	NE.
26	4:02 p. m.	12, 236	−50. 4	13, 397	−52. 9	4	5	330	NE.
27	4:04 p. m.			[2] 1, 417		8	14	([3])	
28	4:00 p. m.	11, 996	−59. 7	[2] 13, 488	−60. 3	42	47	190	E.
29	4:02 p. m.			[2] 3, 923	−57. 6	15	41	145	SE.
30	4:04 p. m.			[2] 13, [illegible]91	−57. 5	44	49	270	SE.

[1] Pressure trace failed at this altitude.
[2] Maximum altitude from 2-theodolite observation.
[3] Not found.

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*

SEPTEMBER 1, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	*°C.*		*P. ct.*	*Mb.*		*M.p.s.*	
4:26	225	991. 4	27. 9		71	26. 71	sw.	3. 4	2 Cu., SW;
	500	955. 3	25. 6		77	25. 30	wsw.	7. 1	Clouds increased
	1, 000	907. 2	21. 5		87	22. 32	sw.	11. 6	to 4 Cu. at 4:40 p.
4:31	1, 120	895. 2	20. 5	0. 83	90	21. 72	sw.	11. 9	m.
	1, 500	856. 9	18. 6		83	17. 80	sw.	12. 7	
	2, 000	807. 4	16. 0		75	13. 64	sw.	8. 8	
4:36	2, 041	804. 1	15. 8	0. 51	74	13. 29	sw.	8. 8	
	2, 500	761. 5	13. 9		67	10. 65	wsw.	5. 1	
	3, 000	727. 4	11. 9		60	8. 36	wnw.	5. 1	
4:42	3, 050	713. 5	11. 7	0. 41	59	8. 11	wnw.	5. 3	
	4, 000	636. 6	7. 3		39	3. 99			
4:49	4, 119	627. 2	6. 8	0. 46	36	3. 56			
4:52	4, 627	589. 3	2. 2	0. 91	36	2. 58			
	5, 000	561. 9	−0. 3		36	2. 15			
4:59	5, 669	517. 1	−4. 9	0. 68	36	1. 47			
	6, 000	494. 7	−7. 5		36	1. 17			
5:05	6, 285	477. 9	−9. 7	0. 78	36	0. 97			
	7, 000	415. 0	−13. 4		34	0. 66			
5:13	7, 856	388. 8	−17. 9	0. 52	31	0. 39			
	8, 000	381. 7	−19. 1		30	0. 34			
5:20	8, 961	334. 6	−27. 1	0. 83	27	0. 14			
	9, 000	332. 8	−27. 5		27	0. 13			
5:24	9, 715	300. 9	−34. 3	0. 95	28	0. 07			
	10, 000	288. 8	−36. 2		27	0. 05			
5:27	10, 170	281. 9	−37. 4	0. 68	26	0. 04			
	11, 000	249. 4	−43. 7		26	0. 02			
5:34	11, 248	240. 6	−45. 6	0. 76	26	0. 02			
	12, 000	211. 3	−50. 7		26	0. 01			
5:41	12, 345	203. 6	−53. 0	0. 67	26	0. 01			
	13, 000	183. 9	−56. 7		26	([1])			
5:47	13, 208	177. 9	−57. 9	0. 57	26	([1])			
	14, 000	157. 3	−60. 7		25	([1])			
5:52	14, 035	155. 9	−60. 8	0. 35	25	([1])			Tropopause.
5:58	14, 821	137. 4	−62. 6	0. 23	26	([1])			
	15, 000	133. 6	−62. 2		26	([1])			
6:03	15, 343	126. 3	−61. 4	−0. 23	26	([1])			

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 2, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
4:15	225	991.9	23.1	-------	85	24.04	nw.	4.0	10 St. Cu., NW.
	500	962.7	21.5	-------	84	21.55	nnw.	8.1	
	1,000	908.3	18.7	-------	82	17.70	-------	-------	Altitude of St. Cu. base—683 M. m. s. l.
4:18	1,217	884.5	17.5	0.56	81	16.21	-------	-------	
4:19	1,372	868.7	18.2	−0.45	81	16.94	-------	-------	
	1,500	856.4	17.6	-------	80	16.10	-------	-------	
4:20	1,527	853.1	17.5	0.45	80	16.01	-------	-------	
4:21	1,617	844.2	17.5	0.00	76	15.21	-------	-------	
	2,000	807.2	15.6	-------	75	13.30	-------	-------	
4:25	2,473	763.4	13.3	0.49	74	11.31	-------	-------	
	2,500	761.0	13.2	-------	73	11.08	-------	-------	
4:29	3,001	716.8	12.3	0.19	58	8.30	-------	-------	
4:33	3,515	674.1	9.7	0.51	29	3.49	-------	-------	
	4,000	634.6	6.6	-------	29	2.82	-------	-------	
4:39	4,613	589.6	2.6	0.65	29	2.13	-------	-------	
4:41	4,852	572.3	−0.7	1.38	28	1.62	-------	-------	
	5,000	561.3	−1.5	-------	30	1.62	-------	-------	
4:46	5,624	519.2	−4.8	0.71	36	1.48	-------	-------	
	6,000	494.8	−5.8	-------	32	1.21	-------	-------	
4:48	6,226	480.9	−6.4	0.27	30	1.07	-------	-------	
4:51	6,619	457.2	−9.7	0.84	38	1.02	-------	-------	
	7,000	434.9	−12.2	-------	35	0.75	-------	-------	
4:58	7,867	388.1	−17.9	0.66	27	0.34	-------	-------	
	8,000	381.4	−18.7	-------	26	0.31	-------	-------	
	9,000	333.2	−24.9	-------	21	0.14	-------	-------	
5:08	9,725	301.2	−29.4	0.62	17	0.07	-------	-------	
	10,000	289.9	−31.5	-------	17	0.06	-------	-------	
5:15	10,931	253.7	−38.4	0.75	17	0.03	-------	-------	
	11,000	251.5	−39.0	-------	17	0.02	-------	-------	
5:20	11,751	224.8	−46.1	0.94	17	0.01	-------	-------	

SEPTEMBER 3, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:03	225	994.6	23.7	-------	50	14.66	nnw.	5.4	1 Cu., NNW.
	500	962.5	20.7	-------	54	13.19	n.	7.5	
4:08	964	912.8	15.6	1.10	61	10.82	nnw.	5.5	
	1,000	909.3	15.3	-------	61	10.61	nnw.	4.9	
	1,500	857.0	11.5	-------	64	8.68	nnw.	5.6	
	2,000	807.4	7.7	-------	68	7.15	nw.	11.7	
4:13	2,073	799.5	7.1	0.77	68	6.86	nw.	12.2	
4:15	2,491	759.6	3.4	0.89	68	5.30	nw.	14.1	
	2,500	757.8	3.4	-------	68	5.30	nw.	14.2	
	3,000	712.5	1.8	-------	44	3.06	nw.	12.4	
4:18	3,283	688.7	0.9	0.32	31	2.02	nw.	11.5	
	4,000	629.8	−0.2	-------	30	1.80	wnw	10.6	
4:22	4,151	618.0	−0.4	0.15	30	1.77	wnw.	13.0	
4:24	4,849	566.1	−4.1	0.53	28	1.22	wnw.	16.8	
	5,000	555.4	−5.2	-------	27	1.07	wnw.	16.7	
	6,000	488.7	−12.5	-------	22	0.46	wnw.	12.7	
4:30	6,206	475.2	−13.9	0.72	21	0.39	wnw.	19.1	
	7,000	427.5	−20.5	-------	21	0.21	wnw.	22.8	
4:35	7,492	399.9	−24.5	0.82	21	0.14	wnw.	20.4	
	8,000	373.6	−28.3	-------	23	0.10	wnw.	27.0	
	9,000	323.3	−36.0	-------	26	0.05	wnw.	32.8	
4:40	9,025	322.5	−36.1	0.76	26	0.05	wnw.	32.6	
	10,000	278.7	−44.0	-------	22	0.02	-------	-------	
4:46	10,268	268.7	−46.2	0.81	21	0.01	-------	-------	
	11,000	239.6	−51.0	-------	21	0.01	-------	-------	
4:53	11,720	215.1	−55.8	0.66	20	(1)	-------	-------	
	12,000	205.7	−57.1	-------	20	(1)	-------	-------	
	13,000	175.7	−62.0	-------	20	(1)	-------	-------	
4:59	13,449	163.2	−64.1	0.48	20	(1)	-------	-------	Tropopause.
	14,000	149.4	−64.9	-------	20	(1)	-------	-------	
5:04	14,475	138.0	−65.5	0.14	20	(1)	-------	-------	
	15,000	126.6	−65.3	-------	20	(1)	-------	-------	
5:10	15,728	112.4	−65.1	−0.03	20	(1)	-------	-------	
	16,000	107.6	−65.3	-------	20	(1)	-------	-------	
5:14	16,932	92.3	−65.9	0.07	20	(1)	-------	-------	

SEPTEMBER 4, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:09	225	992.9	23.2	-------	45	12.81	se.	2.2	3 Ci., WSW.
	500	961.0	21.0	-------	48	11.94	sse.	2.2	
	1,000	907.4	16.9	-------	53	10.21	s.	3.0	
4:14	1,026	904.7	16.7	0.81	53	10.08	s.	2.9	
	1,500	855.1	12.8	-------	60	8.87	ssw.	3.0	
4:17	1,727	832.6	10.9	0.83	63	8.22	ssw.	2.6	
4:18	1,862	819.2	11.4	−0.37	44	5.93	wsw.	2.0	
4:19	1,984	807.3	10.6	0.66	34	4.35	nw.	2.1	
	2,000	805.7	10.6	-------	34	4.35	nw.	2.1	
	2,500	759.6	10.4	-------	29	3.66	nnw.	4.8	
4:23	2,656	744.7	10.3	0.04	28	3.51	nnw.	5.3	
	3,000	715.0	8.7	-------	25	2.81	nnw.	5.5	
4:29	3,666	658.8	5.6	0.47	19	1.73	nw.	3.7	
	4,000	632.0	2.8	-------	19	1.42	nw.	5.3	
4:35	4,511	593.3	−1.5	0.84	19	1.03	nw.	6.4	
	5,000	556.8	−5.2	-------	18	0.71	wnw.	7.2	
4:41	5,422	528.4	−8.3	0.75	18	0.55	-------	-------	

[1] Less than 0.01 mb.

94894—32——3

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 5, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P.ct.	Mb.		M.p.s.	
4:00	225	985.9	26.8	-------	56	19.75	sw.	2.0	Few A. Cu., W., 9 St., WSW.
	500	955.0	26.4	-------	54	18.60	wsw.	6.8	
4:01	587	946.2	26.3	0.14	53	18.15	wsw.	7.1	Altitude of St. base—2,106 M. m. s. l.
	1,000	902.5	22.3	-------	60	16.16	wsw.	8.0	
	1,500	852.8	17.4	-------	69	13.72	wsw.	6.8	
4:07	1,801	822.3	14.5	0.97	74	12.22	wsw.	6.9	
	2,000	804.0	13.1	-------			wsw.	6.9	
	2,500	756.1	9.7	-------	-------	-------	-------	-------	
4:11	2,945	716.9	6.6	0.69	-------	-------	-------	-------	
	3,000	712.6	6.3	-------	-------	-------	-------	-------	R. B. 3:55 p. m.; E. 5:15 p. m.; ⊠ 3:50 p. m.
4:13	3,528	667.5	3.0	0.62	-------	-------	-------	-------	
	4,000	630.0	2.9	-------	-------	-------	-------	-------	
4:15	4,081	623.5	2.9	0.18	-------	-------	-------	-------	
	5,000	557.0	−1.7	-------	-------	-------	-------	-------	
4:19	5,500	522.1	−4.2	0.50	-------	-------	-------	-------	
	6,000	491.0	−7.3	-------	-------	-------	-------	-------	
4:21	6,677	448.9	−11.6	0.63	-------	-------	-------	-------	
	7,000	430.2	−13.7	-------	-------	-------	-------	-------	
	8,000	376.3	−20.3	-------	-------	-------	-------	-------	
4:25	8,650	344.9	−24.6	0.66	-------	-------	-------	-------	
	9,000	328.4	−27.6	-------	-------	-------	-------	-------	
	10,000	285.3	−36.0	-------	-------	-------	-------	-------	
4:31	10,590	262.0	−41.0	0.85	-------	-------	-------	-------	
	11,000	246.9	−44.7	-------	-------	-------	-------	-------	
4:35	11,625	224.4	−50.3	0.90	-------	-------	-------	-------	
	12,000	211.2	−52.1	-------	-------	-------	-------	-------	
	13,000	179.7	−57.0	-------	-------	-------	-------	-------	
4:42	13,771	160.4	−60.7	0.48	-------	-------	-------	-------	Tropopause.
	14,000	154.9	−60.5	-------	-------	-------	-------	-------	
4:46	14,774	136.6	−59.8	−0.09	-------	-------	-------	-------	

SEPTEMBER 6, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
3:59	225	987.0	28.0	-------	52	19.68	w.	1.3	8 Ci., W.
	500	956.4	25.4	-------	55	17.86	w.	2.2	
4:02	804	924.1	22.5	0.95	58	15.82	w.	3.0	
	1,000	904.0	21.1	-------	61	15.27	w.	3.4	
4:04	1,363	866.2	18.4	0.73	67	14.18	w.	4.8	
	1,500	852.0	17.2	-------	67	13.15	w.	5.4	
4:05	1,623	840.3	16.1	0.88	67	12.26	w.	5.9	
4:07	1,887	814.5	13.4	1.02	82	12.61	w.	6.3	
	2,000	802.7	12.8	-------	76	11.23	wsw.	6.2	
4:09	2,354	770.4	11.0	0.51	56	7.35	wsw.	5.2	A. Cu. clouds appeared after balloon was released. 3 A. Cu., W. at 4:28 p. m.
	2,500	757.0	10.0	-------	56	6.88	w.	5.3	
	3,000	712.3	6.6	-------	56	5.45	w.	5.5	
4:12	3,244	691.7	5.0	0.67	56	4.68	wnw.	5.0	
4:13	3,535	667.4	3.0	0.69	50	3.79	w.	5.6	
4:15	3,979	631.6	−0.9	0.88	63	3.57	w.	8.5	
	4,000	630.8	−1.0	-------	63	3.55	w.	8.8	
	5,000	555.0	−4.8	-------	40	1.64	wnw.	11.9	
4:21	5,118	547.1	−5.3	0.39	37	1.45	wnw.	13.1	
	6,000	487.9	−10.8	-------	39	0.95	-------	-------	
4:26	6,489	458.3	−13.9	0.63	41	0.76	-------	-------	
	7,000	427.9	−16.9	-------	43	0.60	-------	-------	
4:31	7,857	381.8	−21.9	0.58	46	0.40	-------	-------	
	8,000	374.6	−23.0	-------	-------	-------	-------	-------	
	9,000	326.1	−30.2	-------	-------	-------	-------	-------	
4:38	9,444	306.3	−33.4	0.72	-------	-------	-------	-------	
	10,000	282.8	−37.7	-------	-------	-------	-------	-------	
	11,000	243.9	−45.4	-------	-------	-------	-------	-------	
4:44	11,406	229.7	−48.6	0.77	-------	-------	-------	-------	
	12,000	209.5	−54.0	-------	-------	-------	-------	-------	
4:51	12,946	180.5	−62.7	0.92	-------	-------	-------	-------	
	13,000	178.8	−63.0	-------	-------	-------	-------	-------	
4:53	13,535	164.0	−66.0	0.56	-------	-------	-------	-------	Tropopause.
4:54	13,879	155.0	−64.4	−0.46	-------	-------	-------	-------	

SEPTEMBER 7, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:00	225	986.8	20.2	-------	96	22.74	se.	1.7	10 Nb., E.
	500	954.1	18.8	-------	96	20.84	-------	-------	
4:06	915	910.7	16.6	0.52	97	18.33	-------	-------	Raining.
	1,000	901.2	16.1	-------	97	17.75	-------	-------	Balloon entered clouds 1 minute after launching.
	1,500	849.0	13.4	-------	97	14.92	-------	-------	
4:14	1,726	827.6	12.2	0.54	97	13.78	-------	-------	
	2,000	800.0	10.8	-------	97	12.56	-------	-------	
	2,500	754.1	8.3	-------	96	10.51	-------	-------	
4:21	2,646	741.1	7.6	0.50	96	10.02	-------	-------	
	3,000	709.5	5.6	-------	95	8.64	-------	-------	
4:29	3,498	667.8	2.7	0.58	93	6.90	-------	-------	
	4,000	626.8	−0.8	-------	90	5.15	-------	-------	
4:32	4,034	624.8	−1.1	0.71	90	5.02	-------	-------	
4:35	4,498	589.3	−4.7	0.78	52	2.15	-------	-------	

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 8, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
4:00	225	992.1	22.5		50	13.64	e.	3.7	2 Ci., W.
	500	960.5	20.1		52	12.24	e.	6.1	
4:03	780	930.2	17.6	0.88	55	11.07	ene.	5.4	
	1,000	905.9	15.5		59	10.39	ene.	4.8	
4:05	1,300	874.8	12.6	0.96	64	9.34	ene.	4.4	
4:06	1,457	858.6	13.5	−0.57	60	9.29	ene.	3.8	
	1,500	852.8	13.3		61	9.32	ene.	3.5	
4:07	1,683	835.8	12.2	0.58	65	9.24	e.	2.5	
	2,000	803.7	10.0		72	8.84	ene.	1.7	
4:10	2,076	797.4	9.5	0.69	74	8.78	ne.	1.0	
4:11	2,264	779.5	9.9	−0.21	78	9.52	nw.	2.8	
	2,500	756.5	8.6		78	8.71	wnw.	5.1	
	3,000	712.1	5.8		79	7.28	wnw.	7.7	
4:20	3,626	660.5	2.3	0.56	80	5.77	wnw.	5.9	
	4,000	629.2	0.8		68	4.40	wnw.	9.1	
4:28	4,914	562.4	−2.9	0.40	40	1.92	wnw.	17.1	
	5,000	555.2	−3.5		40	1.83	wnw.	17.5	
4:35	5,912	495.1	−10.1	0.72	35	0.91	wnw.	24.1	
	6,000	489.4	−10.6		34	0.84	wnw.	23.0	
4:40	6,973	430.8	−16.2	0.57	28	0.42	wnw.	23.8	

SEPTEMBER 9, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:10	225	992.1	22.8		42	11.67	e.	4.0	3 Ci., W., 1 A. Cu., WNW.
	500	960.0	20.7		45	10.99	ene.	5.8	
4:16	854	922.3	18.1	0.75	49	10.18	ene.	5.8	
	1,000	905.5	17.0		50	9.69	e.	3.6	
4:20	1,450	859.8	13.8	0.72	55	8.68	ene.	4.1	
	1,500	853.0	14.4		46	7.55	ene.	4.1	
4:21	1,553	849.3	15.1	−1.26	37	6.35	e.	4.0	
	2,000	804.1	13.4		32	4.92	ne.	2.4	
	2,500	758.0	11.6		27	3.69	nw.	1.2	
4:31	2,521	756.9	11.5	0.37	27	3.66	nw.	1.2	
4:33	2,718	739.3	10.7	0.41	30	3.86	n.	1.4	
4:34	2,830	729.3	10.1	0.54	28	3.46	nnw.	6.0	
	3,000	714.4	9.3		31	3.63	nnw.	4.7	
4:41	3,896	640.8	5.3	0.45	49	4.37	nw.	6.6	
	4,000	632.3	4.4		50	4.18	nw.	7.0	
4:48	4,827	570.8	−2.8	0.87	61	2.96	nw.	11.3	
	5,000	558.5	−3.1		58	2.74	nw.	12.6	
4:50	5,136	549.0	−3.3	0.16	55	2.56	nw.	11.9	
4:51	5,357	533.8	−4.4	0.50	49	2.08	nw.	9.6	
	6,000						nw.	12.8	
	7,000						wnw.	15.4	
	8,000						nw.	31.5	
	9,000						wnw.	28.6	
	10,000						wnw.	43.2	
	11,000						w.	31.6	
5:34	11,508						w.	36.0	

SEPTEMBER 10, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:06	225	989.4	25.3		25	8.07	e.	3.1	1 Ci., WNW.
	500	958.8	22.5		24	6.54	ese.	4.8	
	1,000	903.6	17.4		21	4.17	ese.	5.6	
4:09	1,099	894.0	16.4	1.02	21	3.92	se.	5.8	
4:10	1,418	861.0	15.5	0.28	17	2.99	se.	5.6	
	1,500	852.7	14.9		17	2.88	se.	5.3	
4:11	1,648	837.8	13.7	0.78	17	2.67	se.	4.7	
4:12	1,763	826.4	13.6	0.09	17	2.65	se.	3.8	
	2,000	801.9	12.3		16	2.29	se.	2.5	Pressure record inaccurate; altitudesdetermined from 2-theodolite observation; pressures computed from altitudes and temperatures.
4:13	2,265	778.3	10.9	0.54	14	1.83	se.	1.4	
	2,500	754.2	9.2		16	1.86	ese.	0.7	
	3,000	710.0	5.5		20	1.81	nw.	0.5	
4:18	3,553	665.1	1.4	0.74	25	1.69	w.	2.8	
	4,000	629.3	0.2		24	1,49	wnw.	4.7	
4:20	4,169	615.9	−0.2	0.26	23	1.38	wnw.	4.6	
4:21	4,511	590.1	−2.5	0.67	25	1.24	wnw.	6.0	
4:22	4,585	584.6	−2.1	−0.54	27	1.39	wnw.	6.8	
	5,000	551.0	−5.6				wnw.	8.0	
4:23	5,171	542.6	−7.1	0.85			wnw.	8.5	
4:24	5,404	526.6	−7.6	0.21			wnw.	10.2	
4:25	5,729	504.9	−10.5	0.89			wnw.	11.6	
4:26	5,964	489.7	−10.7	0.09			nw.	11.9	
	6,000	487.0	−10.9				nw.	11.9	
4:28	6,431	460.7	−13.9	0.68			nw.	11.7	
	7,000	426.9	−18.2				wnw.	11.5	
4:33	7,829	381.9	−24.4	0.75			wnw.	12.5	
	8,000	372.0	−25.9				wnw.	11.9	
	9,000	323.7	−31.5				w.	15.8	
4:39	9,435	304.5	−38.2	0.86			w.	18.4	
	10,000	280.0	−43.1				w.	20.2	
4:43	10,639	254.7	−48.9	0.89			wnw.	21.0	
	11,000	241.2	−49.7				wnw.	24.7	
4:45	11,303	230.2	−50.3	0.21			wnw.	25.6	
	12,000	207.2	−54.0				w.	27.4	
4:50	12,817	181.9	−58.4	0.54			w.	27.5	
	13,000	176.9	−59.1				w.	28.0	
	14,000	150.2	−62.8				wnw.	23.4	
4:55	14,341	142.4	−64.1	0.37			wnw.	24.8	
	15,000						wnw.	30.3	
4:59	15,453						wnw.	20.0	

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 11, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
4:16	225	985.4	28.9		50	19.94	se.	1.6	1 Ci., W., 7 Ci. St., W.
	500	955.5	27.5		48	17.64			
4:17	511	954.3	27.4	0.52	48	17.53			
	1,000	903.1	23.6		54	15.74			
	1,500	853.0	19.8		61	14.10			
4:23	1,995	804.4	15.8	0.78	67	12.03			
4:25	2,412	765.7	13.2	0.62	47	7.13			
	2,500	757.5	12.8		47	6.95			
4:26	2,710	739.0	12.0	0.40	46	6.45			
4:27	2,954	717.7	11.2	0.33	41	5.45			
	3,000	712 5	11.0		42	5.51			
4:28	3,144	701.5	10.4	0.42	44	5.55			
4:31	3,772	650 3	6.6	0.61	50	4.87			
4:32	3,942	636.9	5.6	0.59	55	5.00			
	4,000	631.7	5.3		54	4.81			
4:33	4,066	627.4	5.0	0.48	53	4.62			
4:35	4,621	586.0	2.0	0.54	64	4.51			
	5,000	559.0	−1.1		66	3.68			
4:37	5,093	552.5	−1.9	0.83	66	3.45			
4:38	5,536	522.7	−1.6	−0.07	41	2.20			
	6,000	492.9	−4.5		38	1.60			
	7,000	432.4	−10.6		32	0.79			
4:48	7,925	384.1	−16.4	0.62	26	0.38			
	8,000	379.5	−17.0		27	0.38			
	9,000	332.4	−24.4		34	0.23			
4:54	9,442	312.7	−27.7	0.74	38	0.19			
	10,000	289.2	−31.6		38	0.12			
	11,000	250.1	−38.6		39	0.06			
4:59	11,048	248.9	−39.0	0.70	39.	0.06			

SEPTEMBER 12, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:09	225	981.1	28.8		61	24.18	sw.	1.4	1 Cu . SW.
	500	950.0	26.5				sw.	2.8	
4:11	827	916.5	23.7	0.85			sw.	4.0	
	1,000	897.0	22.2				sw.	4.2	
	1,500	847.5	17.9				sw.	3.8	
4:14	1,512	846.8	17.8	0.86			sw.	3.8	
	2,000	799.5	15.5				w.	2.3	
4:19	2,408	762.1	13.5	0.48			nw.	3.3	
	2,500	752.8	12.9				nw.	3.3	
	3,000	708.2	9.8				nnw.	1.5	
4:22	3,071	704.0	9.4	0.62			nnw.	1.6	
4:24	3,486	669.6	8.1	0.31			wnw.	2.4	
	4,000	629.5	4.7				w.	5.5	
4:30	4,930	560.6	−1.4	0.66			w.	6.5	
	5,000	555.0	−1.3				w.	5.5	
4:32	5,194	542.3	−1.2	−0.08			w.	5.4	
	6,000	489.3	−6.3				wnw,	6.2	
4:37	6,535	457.2	−9.7	0.63			w.	10.3	
	7,000	429.9	−12.8				w.	12.6	
4:42	7,926	380.7	−18.9	0.66			w.	12.5	
	8,000	376.8	−19.5				w.	12.2	
4:44	8,265	363.7	−21.7	0.83			w.	11.3	
4:45	8,351	359.5	−21.5	−0.23			w.	11.0	
	9,000	328.5	−24.1				w.	14.2	
4:48	9,383	312.2	−25.6	0.40			wsw.	12.6	
	10,000	286.5	−30.5				wsw.	16.8	
	11,000	248.7	−38.5				w.	24.0	
4:54	11,104	244.7	−39.3	0.80			wsw.	23.8	
	12,000	214.4	−45.0				w.	23.5	
4:59	12,574	196.7	−48.6	0.63			wsw.	21.2	
	13,000	184.0	−51.6				wsw.	23.0	
	14,000	157.5	−58.5				sw.	22.5	
5:04	14,186	153.1	−59.8	0.69			sw.	20.0	
5:06	14,615	142.9	−62.5	0.63					Tropopause.
	15,000	134.3	−63.4						
	16,000	114.2	−65.6						
5:12	16,078	112.6	−65.8	0.23					
5:17	16,798	100.2	−61.1	−0.65					
	17,000	96.8	−61.7						
5:18	17,409	90 8	−62.9	0.29					
	18,000	82.3	−62.0						
	19,000	70 1	−60.4						
5:24	19,028	70.0	−60.4	−0.15					

SEPTEMBER 13, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:02	225	981.2	30.7		47	20.78	s.	3.6	Few Ci. St., W.
	500	951.8	28.3		51	19.64	s.	4.4	
	1,000	899 5	24.0		58	17.32	sw.	5.2	
	1,500	849.0	19.7		66	15.15	w.	6.2	
4:07	1,596	839.3	18.9	0.86	67	14.64	w.	6.3	
4:08	1,832	816.6	17.3	0.68	74	14.62	w.	6.8	
4:09	1,940	806.3	17.5	−0.19	54	10.81	w.	7.1	
	2,000	801.0	17.3		53	10.47	w.	7.2	
4:11	2,256	777.0	16.3	0.38	50	9.27	w.	7.8	
	2,500	756.0	14.9		54	9.15	w.	8.3	
4:14	2,665	740.4	14.0	0.56	57	9.11	w.	7.7	
	3,000	711.1	12.5		45	6.52	wsw.	7.5	
4:16	3,079	704.7	12.2	0.43	42	5.97	wsw.	7.8	
4:20	3,741	650.8	7.3	0.74	41	4.19	wsw.	9.4	

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 13, 1930—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	*°C.*		*P.c.t.*	*Mb.*		*M.b.s.*	
4:21	3,935	635.6	5.2	1.08	48	4.24	w.	9.5	
	4,000	630.6	4.8		47	4.04	w.	9.5	
	5,000	557.2	−1.0		27	1.52	w.	14.2	
4:30	5,278	538.0	−2.6	0.58	22	1.08	w.	14.5	
	6,000	490.9	−7.7		19	0.61	wnw.	17.7	
4:37	6,325	470.7	−10.0	0.71	18	0.47	w.	15.3	
	7,000	430.8	−15.1				w.	17.0	
4:43	7,504	403.0	−18.9	0.75			w.	18.1	
	8,000	377.0	−23.3				w.	20.0	
4:50	8,386	357.3	−26.7	0.88			w.	20.4	
	9,000	328.3	−31.2				w.	26.8	
4:57	9,497	305.6	−34.9	0.74			w.	22.2	
	10,000	284.4	−38.8				w.	23.0	
5:05	10,828	251.6	−45.2	0.77					
	11,000	245.2	−46.6						
5:12	11,855	215.2	−53.3	0.79					
	12,000	210.8	−53.2						
5:18	12,740	187.6	−52.7	−0.07					
	13,000	180.2	−53.9						
	14,000	154.0	−58.4						
5:25	14,183	149.6	−59.2	0.45					Tropopause.
	15,000	131.2	−59.9						
5:31	15,165	127.9	−60.1	0.09					
5:38	15,893	113.9	−58.9	−0.16					

SEPTEMBER 14, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:18	225	981.5	23.5		72	20.87	s.	2.4	5 Ci. St., W. 2 A. St., WSW.
	500	950.4	21.7				sw.	7.5	2 St. Cu., W.
4:19	607	939.2	21.0	0.65			sw.	8.2	
4:20	849	913.5	21.7	−0.29			wsw.	10.8	
	1,000	897.5	20 9				w.	12.0	
	1,500	846.8	18.1				w.	19.6	
	2,000	799.0	15.3				w.	12.4	
4:25	2,259	774.8	13.9	0.55			wsw.	12.2	
	2,500	752.8	12.2				wsw.	13.0	
	3,000	705 0	8.8				w.	18.0	
4:29	3,459	670 8	5.6	0.69			wsw.	23.6	
	4,000	627.4	1.4				wsw.	26.6	
	5,000	552 9	−6.2				wsw.	29.2	
4:35	5,060	549.3	−6.7	0.77			wsw.	29.1	Altitude of A. St. base, 5,150 M. m. s. l.
	6,000	485.0	−11.9						
	7,000	425.0	−17.4						
4:42	7,690	388.6	−21.2	0.55					
	8,000	372.1	−23.6						
	9,000	324.2	−31.4						
	10,000	280 9	−39.2						
4:48	10,229	271.8	−41.0	0.78					
	11,000	241.2	−46.5						
	12,000	207.0	−53.6						
	13,000	177.3	−60.8						
4:57	13,071	175.7	−61.3	0.71					Tropopause.
	14.000	151 9	−62 5						
	15,000	129 3	−63.7						
5:05	15,495	118.7	−64.3	0.12					

SEPTEMBER 15, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
A. m.									
6:16	225	984.1	18.4		99	20.96	sw.	2.4	10 St., SW.
	500	952.7	17.0		98	18.99			Misting.
	1,000	899.2	14.4		96	15.75			Balloon entered clouds 40 secouds after launching.
6:19	1,113	886.8	13.8	0.52	96	15.15			
	1,500	847.0	12.6		78	11.38			
6:22	1,878	809.5	11.5	0.30	60	8.14			
	2,000	798.0	10.9		61	7.95			
	2,500	751.0	8.3		64	7.01			
6:26	2,880	717.4	6.4	0.51	66	6.34			
	3,000	707.1	5.5		73	6.59			
6:27	3,420	671.4	2.2	0.78	98	7.02			
	4,000	623.8	−1.4		99	5.39			
6:31	4,610	578.5	−5.1	0.61	100	4.00			
6:32	4,758	567.8	−4.8	−0.20	88	3.61			
	5,000	550.0	−5.3		67	2.63			
6:33	5,077	545.1	−5.5	0.22	60	2.32			
	6,000	484.1	−9.0		47	1.34			
6:40	6,227	470.3	−9.8	0.37	44	1.17			
6:41	6,709	441.6	−14.2	0.91	53	0.95			
	7,000	424.3	−16.4		56	0.82			
	8,000	371.1	−24.0		65	0.46			
6:48	8,262	358.3	−26.0	0.76	68	0.39			
	9,000	323.2	−31.2		61	0.21			
6:56	9,961	281.9	−38.0	0.71	52	0.08			
	10,000	280.4	−38.3		52	0.08			
	11,000	242.1	−46.8		45	0.03			
7:02	11,162	236.0	−48.2	0.85	44	0.02			
	12,000	207.9	−55.7		43	0.01			

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 15, 1930—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
A. m.	*M.*	*Mb.*	*°C.*		*P.ct.*	*Mb.*		*M.p.s.*	
7:08	12,472	192.5	−60.0	0.90	42	(1)			
	13,000	177.1	−64.4		42	(1)			
7:11	13,248	169.7	−66.5	0.84	42	(1)			Tropopause.
7:13	13,714	157.2	−65.4	−0.24	42	(1)			
7:14	13,888	152.8	−65.4	0.00	43	(1)			

SEPTEMBER 16, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
6:20	225	983.8	15.0		98	16.72	nw.	0.4	5 A. St., SW., 4 A. Cu., SW.
6:21	312	973.8	13.9	1.26	82	13.03	nw.	3.4	
	500	953.4	15.1		66	11.33	nw.	3.4	
6:22	570	944.5	15.5	−0.62	60	10.57	nw.	3.6	
6:24	941	903.9	12.9	0.70	64	9.52	nnw.	3.4	
	1,000	898.6	12.9		60	8.93	nw.	3.5	
6:25	1,189	877.6	12.9	0.00	48	7.14	nw.	4.1	
	1,500	845.6	11.0		67	8.23	w.	7.4	
6:27	1,637	831.8	10.2	0.60	75	9.33	w.	8.0	Altitude of A. Cu. base, 4,765 M. m. S. l.
6:28	1,800	815.7	10.0	0.12	68	8.35	w.	7.6	
	2,000	795.9	8.6		72	8.04	w.	5.2	
6:29	2,026	793.7	8.4	0.71	73	8.04	w.	5.1	
6:31	2,272	770.4	7.5	0.37	56	5.81	w.	5.1	
	2,500	748.9	6.1		66	6.21	w.	5.0	
	3,000	704.7	2.9		87	6.54	wsw.	9.2	
6:35	3,205	687.2	1.6	0.63	96	6.59	wsw.	9.6	
6:37	3,543	658.8	−0.2	0.53	90	5.41	w.	8.3	
	4,000	622.0	−3.4		95	4.38	wsw.	10.8	
6:41	4,436	588.6	−6.5	0.71	100	3.55	wsw.	13.8	
	5,000	547.8	−10.1		84	2.18			
	6,000	479.9	−16.4		56	0.82			
6:49	6,088	474.6	−16.9	0.63	54	0.76			
6:50	6,648	440.4	−19.0	0.38	61	0.70			
	7,000	419.4	−22.8		56	0.45			
6:53	7,108	413.8	−24.0	1.09	54	0.38			
6:55	7,408	397.2	−24.0	0.00	54	0.38			
	8,000	365.7	−27.6		58	0.29			
	9,000	318.0	−33.7		65	0.17			
7:02	9,087	314.2	−34.2	0.61	66	0.16			
7:05	9,544	294.3	−36.0	0.39	54	0.11			
	10,000	275.6	−39.1		54	0.08			
	11,000	238.0	−45.8		54	0.04			
7:14	11,675	214.6	−50.3	0.67	54	0.02			

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Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100\text{ m.}}$	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.									
4:01	225	981.3	25.4		46	14.94	sw.	5.5	7 Cu., W.
	500	949.4	23.0		49	13.77	wsw.	10.9	
	1,000	895.9	18.6		54	11.58	wsw.	13.2	
4:05	1,278	868.7	16.2	0.87	57	10.50	w.	15.1	
	1,500	844 8	14.2		64	10.37	w.	15.8	
	2,000	795.2	9.7		79	9.50			
4:07	2,105	787.1	8.7	0.91	82	9.22			
	2,500	747.6	6.0		87	8.13			
	3,000	703 8	2.5		94	6.87			
4:11	3,289	680.9	0.5	0.69	98	6.20			
4:13	3,583	656.4	0 7	−0.07	53	3 40			
	4,000	622.6	−2.2		52	2.65			
4:15	4,453	588.3	−5.3	0.69	50	1.96			
4:16	4,819	561.6	−4.8	−0.14	37	1.52			
	5,000	548.9	−5.9		36	1.35			
	6,000	483.2	−12.1		28	0.61			
4:22	6,460	454.2	−14.9	0.61	24	0.41			
	7,000	423.2	−18.4		22	0.27			
	8,000	369.4	−24.9		19	0.12			
4:28	8,377	350.5	−27.3	0.65	18	0.09			
	9,000	321.0	−32.1		15	0.05			
4:33	9,860	284.0	−38.8	0.78	12	0.02			
	10,000	278.1	−39.7		12	0.02			
4:36	10,898	243.7	−45.2	0.62	14	0.01			Tropopause.
	11,000	238.9	−45.4		14	0.01			
4:38	11,469	223.7	−46.2	0.18	14	0.01			
	12,000	205.3	−47.5		14	0.01			
	13,000	176.6	−50.0		14	0.01			
4:45	13,554	163.0	−51.3	0.24	14	(1)			
	14,000	151.9	−52.3		14	(1)			
	15,000	130.6	−54.7		14	(1)			
4:50	15,909	113.1	−56.8	0.23	14	(1)			
	16,000	111.7	−56.8		14	(1)			
	17,000	95.4	−57.3		14	(1)			
4:57	18,005	81.3	−57.7	0.04	14	(1)			
	19,000	69.8	−57.8		14	(1)			
	20,000	59.8	−57.9		14	(1)			
5:02	20,447	55.3	−58.0	0.01	14	(1)			
	21,000	50 8	−57.8		14	(1)			
	22,000	43.2	−57.4		14	(1)			
	23,000	37.0	−56.9		14	(1)			
5:07	23,846	32.4	−56.6	−0.04	14	(1)			

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 17, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity		Wind		Remarks
					Relative	Vapor pressure	Direction	Velocity	
A. m.	*M.*	*Mb.*	°*C.*		*P.ct.*	*Mb.*		*M.p.s.*	
6:26----	225	990.2	11.0	-------	78	10.24	w.	2.0	Cloudless.
	500	957.6	13.1	-------	62	9.35	wnw.	10.4	
6:27----	615	945.3	14.0	−0.77	56	8.95	wnw.	10.9	
	1,000	902.7	10.9	-------	59	7.69	wnw.	11.6	
	1,500	849.8	6.8	-------	62	6.13	wnw.	13.1	
6:30----	1,588	840.8	6.1	0.81	63	5.93	wnw.	13.9	
6:31----	1,756	823.8	5.6	0.30	53	4.82	wnw.	15.3	
	2,000	799.8	4.5	-------	51	4.29	w.	17.4	
6:32----	2,171	782.8	3.7	0.46	49	3.90	w.	18.0	
6:33----	2,347	766.1	3.7	0.00	44	3.50	w.	18.5	
	2,500	751.9	3.0	-------	43	3.26	w.	18.4	
	3,000	702.5	0.6	-------	38	2.42	w.	19.7	
6:38----	3,949	627.3	−4.0	0.48	30	1.32	w.	19.7	
	4,000	622.4	−4.2	-------	30	1.29	w.	19.9	
	5,000	548.7	−8.2	-------	29	0.89	w.	23.8	
6:41----	5,036	546.0	−8.3	0.40	29	0.88	w.	24.2	
	6,000	480.8	−15.7	-------	28	0.44	wnw.	32.2	
6:46----	6,254	465.5	−17.7	0.77	28	0.36	wnw.	29.2	
	7,000	420.7	−24.2	-------	27	0.19	-------	-------	
6:50----	7,433	396.5	−28.0	0.87	27	0.13	-------	-------	
	8,000	366.6	−32.7	-------	27	0.08	-------	-------	
6:54----	8,898	321.8	−40.2	0.83	27	0.03	-------	-------	
	9,000	317.1	−41.1	-------	27	0.03	-------	-------	
	10,000	272.9	−49.7	-------	26	0.01	-------	-------	
6:57----	10,016	272.3	−49.8	0.86	26	0.01	-------	-------	
7:01----	10,975	235.1	−51.9	0.22	25	0.01	-------	-------	
	11,000	234.3	−52.1	-------	25	0.01	-------	-------	
7:02----	11,267	224.7	−54.4	0.86	25	0.01	-------	-------	Tropopause.
	12,000	200.2	−54.9	-------	23	(1)	-------	-------	
7:09----	12,663	180.7	−55.4	0.07	22	(1)	-------	-------	
	13,000	171.4	−56.1	-------	22	(1)	-------	-------	
	14,000	146.8	−58.3	-------	22	(1)	-------	-------	
7:16----	14,075	144.7	−58.5	0.22	22	(1)	-------	-------	
	15,000	124.7	−59.4	-------	21	(1)	-------	-------	
7:23----	15,148	122.0	−59.6	0.10	21	(1)	-------	-------	

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P. m.									
4:14----	225	990.0	21.6	-------	28	7.23	w.	6.7	1 Ci., W.
	500	958.1	18.8	-------	28	6.08	w.	10.2	
4:16----	751	931.0	16.2	1.03	28	5.16	w.	12.9	
	1,000	903.5	13.9	-------	30	4.77	w.	11.6	
	1,500	850.4	9.2	-------	35	4.07	w.	12.0	
	2,000	801.0	4.5	-------	40	3.37	wnw.	12.7	
4:21----	2,098	791.6	3.6	0.94	41	3.24	wnw.	13.1	
4:22----	2,383	764.2	2.4	0.42	37	2.69	wnw.	14.9	
	2,500	752.5	2.5	-------	32	2.34	wnw.	15.1	
4:23----	2,564	747.3	2.6	−0.11	29	2.13	wnw.	15.2	
	3,000	708.2	1.3	-------	25	1.68	wnw.	19.4	
4:27----	3,321	680.2	0.3	0.30	22	1.37	wnw.	22.4	
	4,000	624.9	−2.2	-------	28	1.43	wnw.	23.1	
4:29----	4,089	617.8	−2.5	0.36	29	1.44	wnw.	23.8	
	5,000	550.1	−7.5	-------	32	1.04	wnw.	25.9	
4:33----	5,165	538.7	−8.4	0.55	33	0.99	wnw.	25.1	
	6,000	484.3	−14.0	-------	38	0.70	w.	30.5	
4:38----	6,434	456.3	−16.9	0.67	41	0.57	w.	29.5	
	7,000	423.8	−21.2	-------	41	0.38	w.	33.2	
4:44----	7,869	375.4	−27.9	0.77	41	0.20	w.	32.5	
	8,000	369.1	−28.9	-------	41	0.18	w.	32.3	
	9,000	320.7	−36.2	-------	39	0.08	w.	46.8	
4:49----	9,753	286.7	−41.7	0.73	38	0.04	-------	-------	
	10,000	276.6	−43.3	-------	37	0.03	-------	-------	
4:54----	11,004	237.7	−49.9	0.66	34	0.01	-------	-------	
4:57----	11,766	211.4	−53.8	0.51	32	0.01	-------	-------	Tropopause.
	12,000	203.8	−54.1	-------	32	0.01	-------	-------	
	13,000	174.0	−55.5	-------	32	0.01	-------	-------	
5:06----	13,546	160.1	−56.3	0.14	32	0.01	-------	-------	
	14,000	149.0	−58.0	-------	32	(1)	-------	-------	
5:15----	15,000	126.9	−61.9	-------	32	(1)	-------	-------	
	15,141	124.2	−62.4	0.38	32	(1)	-------	-------	

SEPTEMBER 18, 1930

A. m.									
6:33----	225	995.2	10.8	-------	82	10.62	s.	2.0	Few Ci., W.
6:34----	307	985.5	17.2	−7.80	55	10.80	ssw.	3.6	
	500	963.6	16.2	-------	53	9.76	wsw.	5.4	
6:36----	896	919.4	11.1	0.53	50	8.01	w.	5.6	
	1,000	908.4	13.4	-------	51	7.84	w.	6.0	
6:37----	1,382	867.6	10.8	0.68	53	6.86	wnw.	8.1	
	1,500	856.3	10.0	-------	56	6.88	wnw.	8.2	
	2,000	805.1	6.4	-------	67	6.44	nw.	10.1	
6:40----	2,215	784.2	4.9	0.71	72	6.21	nw.	11.2	
	2,500	756.8	5.0	-------	61	5.32	nw.	10.2	
6:42----	2,724	736.7	5.1	−0.04	53	4.65	nw.	10.4	
	3,000	711.4	4.1	-------	50	4.10	wnw.	13.1	
6:44----	3,593	662.0	2.0	0.36	43	3.03	nw.	11.0	
	4,000	630.2	−0.6	-------	41	2.38	nw.	8.1	
	5,000	554.7	−7.1	-------	37	1.25	nw.	9.5	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 18, 1930—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Humidity		Wind		Remarks
					Relative	Vapor pressure	Direction	Velocity	
A. m.	*M.*	*Mb.*	°*C.*		*P.ct.*	*Mb.*		*M.p.s.*	
6:50----	5,476	521.5	−10.2	0.65	35	0.90	nw.	8.7	
	6,000	486.0	−13.9	-------	34	0.63	nw.	8.5	
	7,000	425.3	−21.1	-------	33	0.31	nw.	9.6	
6:57----	7,176	416.2	−22.3	0.59	33	0.28	nw.	9.7	
	8,000	371.0	−31.1	-------	32	0.11	nnw.	10.9	
7:01----	8,386	351.6	−35.3	1.07	31	0.07	nw.	9.8	
	9,000	321.1	−39.8	-------	32	0.04	wnw.	10.3	
	10,000	277.5	−47.0	-------	34	0.02	w.	21.4	
7:07----	10,447	259.2	−50.3	0.73	35	0.01	w.	23.6	
	11,000	237.8	−52.6	-------	34	0.01	wsw.	33.2	
	12,000	203.4	−56.8	-------	33	0.01	wsw.	33.3	
7:12----	12,024	202.9	−56.9	0.42	33	0.01	w.	33.0	Tropopause.
7:15----	12,729	181.5	−57.8	0.13	35	(1)	wsw.	26.0	
	13,000	174.6	−58.3	-------	35	(1)	wsw.	28.7	
	14,000	147.9	−60.0	-------	34	(1)	-------	-------	
7:22----	14,486	137.2	−60.9	0.18	33	(1)	-------	-------	
	15,000	126.1	−60.5	-------	31	(1)	-------	-------	
7:29----	15,783	111.5	−59.8	−0.08	28	(1)	-------	-------	

SEPTEMBER 18, 1930

P. m.									
4:01----	225	991.4	25.5	-------	38	12.41	sw.	2.7	Few Ci., few A.Cu.
--------	500	959.9	22.6	-------	41	11.25	ssw.	5.1	
--------	1,000	906.0	17.4	-------	47	9.34	ssw.	6.8	
4:04----	1,038	902.4	17.0	1.05	47	9.11	sw.	6.8	
--------	1,500	853.6	13.1	-------	53	7.99	sw.	6.9	
4:06----	1,861	818.3	10.0	0.85	58	7.12	wsw.	7.3	
4:07----	1,998	804.9	9.7	0.22	60	7.22	w.	8.8	
4:08----	2,426	764.3	7.5	0.51	68	7.05	nw.	9.4	
--------	2,500	758.1	7.7	-------	64	6.73	nw.	9.5	
4:09----	2,620	746.5	8.0	−0.26	58	6.22	nnw.	10.1	
4:10----	2,803	730.1	6.8	0.66	62	6.13	nnw.	13.1	
--------	3,000	712.2	6.0	-------	55	5.14	nnw.	13.9	
4:12----	3,283	688.5	4.9	0.40	45	3.90	nnw.	12.0	
4:14----	3,851	641.9	1.3	0.63	48	3.22	nnw.	7.8	
--------	4,000	630.4	0.5	-------	45	2.85	nw.	7.4	
4:17----	4,739	574.3	−3.2	0.51	30	1.41	w.	5.9	
--------	5,000	555.4	−4.1	-------	27	1.17	wsw.	5.4	
4:19----	5,207	541.2	−4.9	0.36	25	1.02	wsw.	5.2	
--------	6,000	488.3	−12.2	-------	25	0.54	w.	8.0	
4:27----	6,967	429.7	−21.2	0.93	24	0.22	w.	8.7	
--------	7,000	427.4	−21.5	-------	24	0.22	w.	8.7	
--------	8,000	372.8	−31.0	-------	24	0.08	wnw.	12.3	
4:33----	8,386	352.8	−34.6	0.94	24	0.06	wnw.	12.3	
--------	9,000	322.6	−41.8	-------	24	0.02	w.	11.4	
4:40----	9,649	292.9	−49.5	1.18	24	0.01	wsw.	12.1	
--------	10,000	277.3	−50.3	-------	24	0.01	wsw.	17.0	
--------	11,000	248.5	−52.7	-------	23	0.01	sw.	24.7	
4:47----	11,509	220.0	−53.9	0.24	22	0.01	wsw.	38.8	
--------	12,000	204.3	−55.9	-------	22	(1)	sw.	34.0	
4:53----	12,534	187.3	−58.1	0.41	22	(1)	wsw.	36.2	Tropopause.
--------	13,000	174.4	−58.8	-------	22	(1)	wsw.	34.6	
4:59----	13,733	154.8	−59.8	0.14	22	(1)	wsw.	29.3	
--------	14,000	148.3	−60.0	-------	22	(1)	w.	30.7	
5:04----	14,946	127.5	−60.5	0.06	22	(1)	wsw.	26.7	
--------	15,000	126.2	−60.8	-------	22	(1)	wsw.	26.9	
5:05----	15,298	120.5	−62.7	0.62	20	(1)	wsw.	21.3	

SEPTEMBER 19, 1930

A. m.									
6:33----	225	991.4	16.1	-------	69	12.63	s.	3.1	6 A. Cu., W.
6:33½--	345	977.5	15.2	0.75	67	11.58	s.	8.4	
6:34----	478	962.3	18.1	−2.18	53	11.01	ssw.	10.8	
--------	500	958.9	18.1	-------	53	11.01	ssw.	11.2	
6:35----	663	941.7	18.5	−0.22	53	11.29	sw.	11.5	
6:35½--	865	919.8	19.4	−0.45	48	10.82	sw.	11.8	
--------	1,000	905.0	18.8	-------	49	10.64	sw.	11.4	
--------	1,500	853.2	16.5	-------	52	9.77	wsw.	9.3	
--------	2,000	805.5	14.2	-------	56	9.07	wsw.	7.5	
6:40----	2,008	804.3	14.2	0.45	56	9.07	wsw.	7.5	
--------	2,500	760.0	10.0	-------	58	7.12	w.	8.2	
--------	3,000	715.0	5.8	-------	60	5.53	wnw.	10.4	
6:45----	3,627	660.8	0.5	0.85	62	3.92	wnw.	9.1	
--------	4,000	631.1	−2.4	-------	65	3.26	w.	11.0	
--------	5,000	554.5	−10.3	-------	73	1.86	w.	8.2	
6:51----	5,189	541.7	−11.8	0.79	75	1.67	-------	-------	
6:52----	5,444	524.0	−10.1	−0.67	70	1.82	-------	-------	
--------	6,000	487.3	−13.5	-------	62	1.19	-------	-------	
6:58----	6,916	431.7	−19.2	0.62	48	0.54	-------	-------	
--------	7,000	427.3	−19.6	-------	48	0.52	-------	-------	
--------	8,000	372.8	−24.8	-------	48	0.31	-------	-------	
7:06----	8,770	335.0	−28.7	0.51	48	0.21	-------	-------	
--------	9,000	324.9	−30.6	-------	48	0.17	-------	-------	
--------	10,000	281.7	−39.0	-------	47	0.07	-------	-------	
--------	11,000	242.7	−47.3	-------	46	0.02	-------	-------	
7:14----	11,027	241.5	−47.5	0.83	46	0.02	-------	-------	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*

SEPTEMBER 19, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
4:10	225	987.4	27.4		38	13.88	s.	5.4	1 A. Cu., SW.
	500	955.8	24.8				ssw.	11.1	
4:12	726	932.2	22.6	0.96			ssw.	11.4	
4:13	943	909.1	21.5	0.51			sw.	16.4	
	1,000	902.9	21.0				sw.	16.8	
4:14	1,366	965.2	17.5	0.95			sw.	16.4	
4:15	1,467	855.0	17.8	−0.30			sw.	15.0	
	1,500	852.2	17.5				wsw.	14.3	
4:16	1,792	822.9	15.3	0.77			wsw	16.1	
	2,000	803.5	14.0				wsw.	16.6	
	2,500	756.2	10.8				wsw.	15.4	
4:19	2,818	727.7	8.8	0.63			wsw.	14.6	
4:20	2,920	718.8	9.2	−0.39			wsw.	14.7	
	3,000	712.8	8.5				w.	14.9	
4:21	3,272	688.7	6.1	0.88			w.	15.0	
	4,000	629.7	−0.6				w.	10.2	
4:25	4,278	607.8	−3.1	0.91			w.	10.0	
	5,000	554.5	−8.1				nw.	10.3	
4:30	5,513	518.7	−11.6	0.69			wnw.	8.7	
	6,000	486.9	−14.1				w.	11.5	
4:36	6,728	441.9	−17.9	0.52			w.	16.3	
	7,000	426.4	−20.0				w.	15.3	
	8,000	372.2	−27.6				w.	14.8	
4:42	8,173	362.7	−28.9	0.76			wnw.	13.2	
	9,000	323.0	−35.7				wnw.	9.8	
4:49	9,874	284.1	−42.9	0.82			w.	17.4	
	10,000	279.1	−43.5				w.	17.8	
	11,000	240.2	−48.5				w.	22.2	
4:56	11,433	224.7	−50.6	0.49			wsw.	26.8	
	12,000	205.7	−54.4				w.	25.4	
4:59	12,552	188.7	−58.0	0.66			wsw.	30.0	Tropopause.
	13,000	175.9	−58.1				wsw.	36.0	
	14,000	150.0	−58.2				wsw.	38.3	
5:08	14,444	139.8	−58.3	0.02			w.	27.6	
	15,000						w.	24.7	
5:13	15,519						wsw.	24.0	

SEPTEMBER 20, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
A. m.									
6:34	225	991.7	13.0		79	11.83	n.	2.8	7 St. Cu., W.
6:35	394	971.9	13.0	0.00	72	10.79	n.	7.0	
	500	959.6	12.3		72	10.30	n.	8.6	
6:36	884	916.7	9.9	0.63	72	8.78	n.	11.2	
	1,000	903.0	10.9		72	9.39	n.	8.6	
6:36½	1,022	901.7	11.1	−0.87	72	9.51	n.	8.3	
6:37	1,184	884.3	10.4	0.43	82	10.34	nnw.	6.1	
6:38	1,359	865.9	10.9	−0.29	84	10.95	w.	6.8	
	1,500	850.4	11.8		85	11.76	w.	8.5	
6:39	1,663	835.1	12.8	−0.63	86	12.71	wsw.	12.9	
	2,000	802.0	11.2		86	11.44	w.	15.4	
6:42	2,500	755.5	8.7	0.49	86	9.68	w.	18.8	
	3,000	710.1	5.2		86	7.60			
6:45	3,623	658.3	0.8	0.70	86	5.56			
6:46	3,868	638.8	1.8	−0.41	70	4.86			
	4,000	627.5	0.9		71	4.63			
6:48	4,792	568.9	−4.7	0.70	74	3.06			
	5,000	554.4	−6.4		77	2.76			
6:50	5,215	538.9	−8.2	0.83	80	2.46			
6:51	5,747	503.2	−10.6	0.45	60	1.49			
	6,000	486.9	−12.3		60	1.28			
6:53	6,545	453.2	−16.1	0.69	60	0.91			
	7,000	426.5	−18.5		58	0.70			
6:55	7,281	410.8	−20.0	0.53	56	0.58			
6:57	7,696	388.3	−23.8	0.92	54	0.39			
	8,000	372.7	−25.7		52	0.31			
	9,000	324.5	−32.0		47	0.15			
7:05	9,470	303.0	−35.0	0.63	45	0.10			
7:08	9,993	280.9	−40.3	1.01	43	0.05			
7:10	10,377	265.5	−41.5	0.31	43	0.05			
	11,000	241.9	−48.1		43	0.02			
7:14	11,271	232.1	−51.0	1.06	43	0.02			

SEPTEMBER 20, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.									
:10	225	989.9	20.7		31	7.57	nw.	3.6	2 Ci. St., W.
	500	958.5	18.3				w.	3.8	
:12	779	927.5	15.8	0.88			wnw.	4.1	Pressure record poor; altitutdes determined from 2-theodolite observations; pressures computed from altitudes and temperatures.
	1,000	904.0	13.9				wnw.	4.9	
:15	1,457	855.3	10.1	0.84			wnw.	6.7	
	1,500	851.4	9.9				wnw.	6.9	
	2,000	800.0	7.5				w.	8.8	
:17	2,222	779.4	6.4	0.48			w.	11.1	
:18	2,399	762.7	7.5	−0.62			w.	12.0	
	2,500	753.5	6.8				w.	12.3	
:20	2,757	730.1	5.0	0.70			w.	13.1	

TABLE 2.—*Tabulated data of sounding-balloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 20, 1930—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	M.	Mb.	°C.		P. ct.	Mb.		M.p.s.	
4:21	2,950	713.0	5.2	−0.10			w.	14.5	
	3,000	709.1	4.9				w.	14.9	
4:24	3,921	632.2	0.1	0.52			w.	18.6	
	4,000	626.0	−0.4				w.	18.7	
4:28	4,889	559.4	−6.1	0.64			w.	21.0	
	5,000	550.9	−6.0				w.	20.9	
4:29	5,133	542.3	−5.9	−0.08			w.	20.1	
	6,000	485.0	−13.6				w.	23.8	
4:35	6,340	463.5	−16.6	0.89			w.	25.5	
4:36	6,709						w.	24.5	

SEPTEMBER 21, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:27	225	986.5	23.1		35	9.90	s.	3.6	Cloudless.
4:28	437	962.8	23.1	0.00	34	9.62	ssw.	8.3	
	500	954.8	22.6		34	9.33	ssw.	8.5	
	1,000	900.7	18.3		36	7.57	ssw.	10.8	
4:31	1,443	856.1	14.6	0.85	38	6.32	sw.	12.2	
	1,500	850.0	14.6		39	6.48	sw.	12.4	
4:32	1,678	832.7	14.5	0.41	41	6.77	wsw.	13.3	
4:33	1,945	806.7	13.5	0.37	46	7.12	w.	15.5	
	2,000	800.9	13.7		45	7.06	w.	16.1	
4:34	2,079	794.0	13.9	−0.30	44	6.99	w.	17.0	
	2,500	755.0	10.6		48	6.13	wnw.	19.6	
	3,000	710.9	6.7		53	5.20	wnw.	24.4	
4:38	3,368	679.7	3.9	0.78	57	4.60	wnw.	23.4	
4:39	3,563	663.6	4.1	−0.10	52	4.26	w.	21.9	
	4,000	628.5	0.7		52	3.34	w.	22.4	
4:42	4,668	578.1	−4.5	0.78	52	2.19	w.	27.3	
4:43	4,856	564.4	−4.3	−0.11	50	2.14	w.	28.8	
	5,000	554.0	−5.2		48	1.91	w.	29.3	
4:46	5,671	508.5	−9.2	0.60	41	1.15	w.	28.2	
4:47	5,884	494.7	−8.9	−0.14	38	1.09	wnw.	26.8	
	6,000	486.4	−9.9		38	1.00	wnw.	25.2	
4:49	6,406	462.2	−13.6	0.90	38	0.72	w.	29.4	
	7,000	425.7	−18.6		37	0.44	w.	29.4	
	8,000	372.8	−27.0		34	0.18	w.	32.3	
4:53	8,216	361.8	−28.8	0.84	34	0.15	w.	35.2	
	9,000	325.9	−35.6		33	0.07	w.	39.4	
4:59	9,717	291.8	−41.9	0.87	33	0.03	w.	33.8	
	10,000	282.9	−44.0		33	0.03	w.	34.7	
	11,000	241.0	−51.5		33	0.01	w.	33.6	
5:04	11,057	238.5	−51.9	0.75	33	0.01			

SEPTEMBER 24, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt/100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
3:58	225	989.0	23.9		77	22.85	s.	4.5	6 A. St., SW 4 St., SW.
3:59	316	978.8	23.5	0.44			ssw.	8.1	
	500	958.9	22.6				ssw.	11.2	
4:00	599	947.6	22.1	0.49			ssw.	12.1	
	1,000	905.4	19.7				sw.	17.3	
4:04	1,458	857.7	16.9	0.61			sw.	20.0	
	1,500	854.0	16.7				sw.	19.9	
	2,000	805.0	13.9				sw.	22.0	
4:07	2,262	780.0	12.4	0.56			sw.	21.8	
	2,500	758.5	11.0				sw.	21.4	
	3,000	715.0	8.1				sw.	20.6	
4:11	3,137	702.2	7.3	0.58			sw.	20.1	
4:14	3,932	637.0	2.6	0.59					
	4,000	632.1	2.4						
	5,000	558.1	−1.0						Intermittent showers all day; Sprinkling rain at time of flight.
4:18	5,165	546.5	−1.6	0.34					
	6,000	492.2	−7.5						
4:24	6,474	462.4	−10.8	0.70					
	7,000	431.3	−14.0						
	8,000	377.1	−20.0						
4:32	8,212	367.3	−21.3	0.60					
	9,000	330.0	−27.1						
4:38	9,548	305.5	−31.1	0.73					
	10,000	287.2	−34.7						
4:45	10,869	252.6	−41.8	0.81					
	11,000	247.9	−43.0						
4:51	11,795	219.8	−50.2	0.91					
	12,000	213.0	−52.1						
4:56	12,650	192.4	−58.2	0.94					
	13,000	181.9	−60.5						
5:03	13,479	168.4	−63.7	0.66					
	14,000	154.8	−67.4						
5:10	14,357	145.7	−69.9	0.71					Tropopause.
	15,000	130.9	−66.7						
5:16	15,020	130.5	−66.6	−0.50					
5:21	15,461	121.4	−64.0	−0.59					

TABLE 2.—*Tabulated data of sounding-baloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 26, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:02	225	980.7	11.2		69	9.18	w.	9.4	10 St. Cu., WSW.
4:03	411	959.1	11.0	0.11	73	9.58	wsw.	13.5	
	500	953.6	10.2		76	9.45	wsw.	15.7	
	1,000	892.6	5.8		92	8.48			Base of St. Cu.= 867 M. m.s.l.
4:07	1,242	867.0	3.6	0.89	100	7.90			
	1,500	839.3	2.2		99	7.09			
	2,000	788.0	−0.5		98	5.74			
4:15	2,492	742.1	−3.2	0.54	96	4.50			
	2,500	740.8	−3.0		94	4.48			
4:16	2,577	734.2	−1.5	−2.00	79	4.27			
4:18	2,900	705.1	0.0	−0.46	58	3.54			
	3,000	696.0	−0.5		58	3.40			
4:22	3,638	642.7	−3.5	0.47	56	2.56			
4:23	3,808	629.0	−1.8	−1.00	43	2.27			
	4,000	614.5	−2.0		41	2.12			
4:27	4,461	579.4	−2.6	0.12	37	1.82			
	5,000	542.1	−4.1		28	1.22			
4:35	5,752	491.9	−6.2	0.28	15	0.55			
	6,000	477.1	−7.8		15	0.48			
	7,000	418.7	−14.4		13	0.23			
4:42	7,211	406.9	−15.8	0.66	13	0.20			
	8,000	366.5	−20.9		12	0.11			
4:49	8,519	341.2	−24.3	0.65	12	0.08			
	9,000	319.4	−28.6		13	0.66			
4:56	9,716	288.6	−35.1	0.90	14	0.03			
	10,000	277.4	−36.8		14	0.03			
5:01	10,710	249.9	−41.0	0.59	14	0.02			
5:02	10,948	241.3	−40.2	−0.34	14	0.02			
	11,000	239.9	−40.6		14	0.02			
	12,000	206.6	−48.4		12	0.01			
5:08	12,236	199.1	−50.4	0.79	12	(1)			Tropopause.
	13,000	177.3	−52.0		12	(1)			
5:16	13,397	166.6	−52.9	0.22	12	(1)			

SEPTEMBER 28, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:00	225	990.5	17.0		33	6.40	w.	5.7	Cloudless.
	500	957.5	14.5		35	5.78	w.	8.2	
	1,000	923.8	10.1		38	4.70	w.	10.4	
4:03	1,241	877.2	7.9	0.90	40	4.26	w.	11.0	
	1,500	850.0	5.7		43	3.94	w.	10.8	
4:05	1,987	800.5	1.7	0.83	48	3.31	wnw.	15.9	
	2,000	799.5	1.8		47	3.27	wnw.	16.2	
4:06	2,169	782.6	3.4	−0.93	30	2.34	wnw.	18.9	
	2,500	751.0	2.3		47	3.39	nw.	29.6	
4:08	2,510	750.4	2.3	0.32	48	3.46	nw.	29.8	Pressure trace questionable; altitudes determined from 2-theodolite observations; pressure computed from altitudes and temperatures.
4:09	2,902	714.6	−0.2	0.64	57	3.43	nw.	30.6	
	3,000	705.0	−0.6		57	3.31	nw.	30.6	
4:11	3,751	642.2	−4.0	0.45	57	2.50	wnw.	28.2	
	4,000	622.1	−5.0		53	2.14	wnw.	28.8	
4:13	4,353	594.9	−6.4	0.40	48	1.72	wnw.	28.7	
	5,000	547.7	−10.5		40	1.00	wnw.	29.8	
4:17	5,790	493.6	−15.5	0.63	30	0.48	wnw.	25.8	
	6,000	480.9	−17.0		30	0.42	wnw.	21.5	
	7,000	420.4	−24.0		29	0.21	wnw.	23.2	
	8,000	365.3	−31.1		28	0.10	wnw.	30.2	

[1] Less than 0.01 mb.

TABLE 2.—*Tabulated data of sounding-baloon ascents at Royal Center, Ind., during September, 1930*—Continued

SEPTEMBER 28, 1930—Continued

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
P. m.	*M.*	*Mb.*	°*C.*		*P. ct.*	*Mb.*		*M. p. s.*	
4:25	8,613	334.7	−35.4	0.70	28	0.06	wnw.	26.8	
	9,000	316.8	−38.5		27	0.04	wnw.	24.7	
	10,000	273.2	−46.5		26	0.02	wnw.	30.7	
4:31	10,503	253.0	−50.5	0.80	25	0.01	wnw.	29.1	
	11,000	234.1	−53.6		25	0.01	w.	26.7	
4:37	11,996	200.4	−59.7	0.62	25	(1)	w.	40.0	Tropopause.
	13,000	171.0	−60.1		25	(1)	w.	31.4	
4:41	13,423	159.6	−60.3	0.04	25	(1)	w.	26.7	
4:42	13,488						w.	26.0	

SEPTEMBER 29, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:02	225	992.1	17.0		47	9.11	n.	4.2	Few A. Cu., W.
	500	960.0	14.4		51	8.37	nnw.	6.0	
	1,000	905.2	9.7		60	7.22	nnw.	4.3	
4:06	1,261	876.7	7.2	0.95	64	6.50	nw.	7.3	
4:07	1,476	854.1	7.5	−0.14	64	6.64	nw.	10.9	
	1,500	851.5	7.4		64	6.59	nw.	11.1	
	2,000	800.1	5.5		64	5.78	wnw.	17.0	
4:09	2,148	786.9	4.9	0.39	64	5.54	w.	19.3	
	2,500	755.0	3.2		60	4.61	w.	21.6	
4:11	2,539	750.0	3.0	0.48	60	4.55	w.	21.6	
	3,000	709.7	−0.7		68	3.92	wnw.	23.7	
4:15	3,353	677.5	−3.5	0.80	74	3.39	wnw.	25.1	
4:16	3,769	642.7	−4.9	0.34	50	2.04	wnw.	23.0	
4:17	3,923	630.3	−4.5	−0.26	43	1.81	wnw.	23.0	

SEPTEMBER 30, 1930

Time 90th mer.	Altitude, M. S. L.	Pressure	Temperature	Δt 100 m.	Humidity: Relative	Humidity: Vapor pressure	Wind: Direction	Wind: Velocity	Remarks
4:04	225	997.6	15.3		50	8.70	n.	5.5	Few Ci., NW. Cu., NW.
	500	965.0	13.1		53	7.99	n.	6.6	
	1,000	909.4	9.1		59	6.82	n.	6.4	Pressure trace questionable; altitude determined from 2-theodolite observations; pressure computed from altitudes and temperatures.
	1,500	856.2	5.1		66	5.79	nnw.	5.1	
4:09	1,784	826.4	2.8	0.80	69	5.15	nnw.	4.9	
	2,000	805.0	4.1		54	4.42	nnw.	8.8	
4:11	2,230	782.4	5.5	−0.61	39	3.52	nnw.	11.6	
	2,500	757.0	5.3		33	2.94	nnw.	10.6	
4:11½	2,547	752.6	5.3	0.06	32	2.85	nnw.	10.4	
4.12	2,628	745.2	5.5	−0.25	30	2.71	nnw.	10.5	
4:14	3,002	711.7	5.0	0.13	28	2.44	nnw.	18.4	
	4,000	626.0	−1.3		31	1.70	nw.	18.6	
	5,000	551.1	−7.5		34	1.11	nw.	19.7	
	6,000	486.1	−13.8		37	0.69	nw.	20.2	
4:23	6,337	465.5	−15.9	0.63	38	0.59	nw.	21.4	
	7,000	427.0	−20.5		38	0.38	nw.	20.9	
	8,000	372.5	−27.4		38	0.19	nw.	21.9	
	9,000	323.2	−34.3		38	0.09	nw.	27.6	
4:33	9,531	299.1	−38.0	0.69	38	0.06	nw.	26.7	
	10,000	279.5	−41.4		37	0.04	nw.	25.4	
	11,000	241.6	−48.7		36	0.01	wnw.	28.0	
	12,000	206.6	−56.0		35	0.01	wnw.	32.6	
4:43	12,118	202.4	−56.9	0.73	35	0.01	nw.	32.8	
	13,000						nw.	34.0	
4:48	13,591						nw.	38.0	

[1] Less than 0.01 mb.

RECORD SHORT-PERIOD RAINFALLS IN FLORIDA

GEORGE V. FISH

[Weather Bureau Office, Tampa, Fla.]

The following is a study of record rainfalls for 5, 10, 15, and 30 minutes and for 1, 2, and 24 hours, together with the maximum monthly amounts occurring on or near the coast of Florida, as determined from the data of the first-order Weather Bureau stations in that State.

This subject is important owing to its value to architects, engineers, and all engaged in the aviation industry. They desire to ascertain just what they may expect in the future as inferred from the records of what has happened in the past.

Architects have to consider these values in planning the roofs and foundations of buildings. Engineers consider carefully the amount of run-off they may expect in the season of summer showers. In so far as may be considered justified, they allow a considerable margin for the exceptionally heavy rainfall.

Since an east coast mail pilot was caught in the thunderstorm as reported by James W. Smith (MONTHLY WEATHER REVIEW, vol. 58, March, 1930, pp. 117–118) every commercial pilot in Florida has had an increased respect for these tremendous downpours of rainfall. The tendency of pilots, previous to that time, was to take off with their ship, try to find a "hole" in the thick weather and get the mail through to their destination. Since that time they have made many flights in weather that was far from good, but only after they had received reports assuring them of frequent breaks in the threatening weather confronting them.

The tables show that by far the greater number of these record amounts occurred in connection with thunderstorms. On the west coast of Florida, from Pensacola to Tampa, practically all the record falls occurred in thunderstorms, though the tabulated amounts for Apalachicola indicate that tropical storms may be a factor in that record. The existing short-period records for Apalachicola are comparatively brief. It is believed that

a much longer record would eliminate tropical storms as the controlling factor, except possibly for the 24-hour and monthly amounts.

It is interesting to note that the greatest monthly catch at Apalachicola, 27.73 inches in September, 1924, is only 0.13 inch less than the maximum for the State, reported by first-order stations, that is, 27.86 inches at Miami in October, 1908. It should be noted that this later amount was recorded before a first-order station was established at Miami.

Both of these extremely heavy monthly rainfalls may be traced to the passage of tropical storms. They are likely to stand for some time as records.

It is thought that but few heavy rainfalls are recorded in Florida during the late fall and winter months. The tables, however, indicate that rains approximating an inch in 30 minutes may occur during practically all the months of the year, at all Florida stations, though it is evident that the short-period amounts are decidedly greatest in the summer and early fall months.

The heaviest rainfall for five minutes, 1.05 inches, occurred at Tampa, in September, 1924, during an afternoon thundershower. The same storm caused a downpour of 1.66 inches at Tampa in a 10-minute period. Pensacola has the record for the next three periods, 2.27 inches in 15 minutes; 3.63 inches in 30 minutes, and 4.27 inches in 1 hour, all occurring during a thunderstorm in October, 1909. Key West, with a record rainfall of 7.08 inches in two hours stands well ahead of all the other stations for that period. Miami has recorded the greatest amount in 24 hours, 15.10 in November, 1925. It, too, occurred in connection with a thunderstorm.

Precipitation, record amounts

APALACHICOLA

[ꓘ thunderstorm; DG, disturbance in Gulf; GR, general rain; TD, tropical disturbance; H, hail]

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.36	0.29	0.40	0.53	0.78	0.40	0.42	0.44	0.56	0.65	0.38	0.32
	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	GR	ꓘ	ꓘ H	ꓘ	ꓘ	ꓘ
Year	1923	1929	1928	1928	1923	1926	1929	1922	1927	1927	1930	1924
10 minutes	0.54	0.51	0.61	0.86	1.28	0.68	0.78	0.72	0.88	1.15	0.63	0.50
	ꓘ DG	ꓘ	1925 ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ H	ꓘ	ꓘ	ꓘ
Year	1926	1929	1928 ꓘ	1928	1923	1926	1931	1924	1927	1927	1930	1922
15 minutes	0.74	0.66	0.80	1.07	1.65	0.93	1.02	0.96	0.98	1.38	0.75	0.59
	ꓘ DG	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ
Year	1926	1929	1925	1928	1923	1926	1931	1922	1930	1927	1930	1922
30 minutes	1.06	1.05	1.39	1.72	2.27	1.52	1.45	1.62	1.38	2.10	1.04	0.80
	ꓘ DG	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	GR
Year	1926	1929	1928	1928	1923	1929	1924	1922	1930	1927	1930	1922
1 hour	1.20	1.46	2.06	2.64	2.72	2.41	1.62	2.53	1.75	2.73	1.55	1.23
	ꓘ DG	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	TD	ꓘ	ꓘ	GR
Year	1926	1929	1928	1928	1923	1929	1924	1922	1924	1927	1930	1922
2 hours	1.74	2.09	2.66	3.75	2.97	2.82	1.65	3.10	2.47	3.09	2.24	1.50
	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	TD	ꓘ	ꓘ	GR
Year	1930	1929	1929	1928	1923	1929	1923	1922	1924	1927	1930	1922
24 hours	5.15	3.61	5.87	6.32	4.70	5.41	7.14	7.04	10.12	5.65	5.84	6.02
		DG	ꓘ	ꓘ				ꓘ		ꓘ	ꓘ	
Year	1915	1924	1928	1929	1907	1910	1916	1925	1906	1927	1930	1918
Month	11.89	10.44	13.97	18.62	9.27	14.90	17.29	14.09	27.73	9.12	8.67	15.88
			ꓘ	ꓘ					TD		ꓘ	
Year	1915	1919	1928	1928	1922	1910	1921	1912	1924	1915	1930	1918

Greatest amounts in 24 hours and for the month for period November 1903, to date. All other amounts for period since July, 1922. No information available as to conditions attending rainfall prior to establishment of first-order station in July, 1922.

Precipitation, record amounts—Continued

JACKSONVILLE

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.43	0.42	0.53	0.62	0.57	0.67	0.67	0.78	0.62	0.50	0.37	0.56
Year	1925	1922	1930	1907	1907	1901	1917	1901	1891	1904	1903	1905
10 minutes	0.53	0.70	0.91	0.91	0.94	1.18	1.19	1.20	1.18	0.72	0.55	0.77
Year	1925	1922	1905	1907	1919	1901	1917	1907	1891	1904	1896	1905
15 minutes	0.82	0.97	1.25	1.09	1.24	1.44	1.65	1.59	1.54	1.06	0.71	0.78
Year	1895	1922	1905	1907	1919	1901	1917	1907	1891	1904	1896	1905
30 minutes	1.01	1.53	1.53	1.21	1.74	2.07	2.47	2.13	3.12	1.26	0.97	0.97
Year	1895	1902	1905	1907	1919	1901	1917	1920	1889	1904	1914	1927
1 hour	1.13	1.61	1.89	1.70	2.34	3.13	2.93	2.65	3.12	1.82	1.19	1.27
Year	1895	1902	1930	1893	1903	1901	1917	1920	1889	1894	1920	1927
2 hours	1.90	1.61	2.23	2.04	3.78	3.21	3.01	2.72	3.14	2.15	1.50	1.60
Year	1915	1902	1930	1900	1903	1901	1917	1920	1907	1894	1920	1927
24 hours	3.09	4.16	4.47	4.81	9.06	7.66	4.89	6.18	9.86	5.15	3.75	4.97
Year	1881	1920	1901	1900	1903	1919	1926	1905	1984	1890	1884	1916
Month	9.12	9.16	10.00	8.19	14.80	13.79	14.97	10.97	21.79	16.25	6.09	7.76

KEY WEST

	January	February	March	April	May	June	July	August	September	October	November	December
		ꓘ	ꓘ	ꓘ	ꓘ				ꓘ		ꓘ	ꓘ
5 minutes	0.46	0.39	0.60	0.53	0.64	0.65	0.53	0.57	0.49	0.50	0.46	0.39
Year	1924	1925	1911	1904	1925	1899	1912	1926	1918	1912	1911	1912
		ꓘ	ꓘ	ꓘ	ꓘ		ꓘ		ꓘ		ꓘ	ꓘ
10 minutes	0.81	0.61	0.93	1.02	1.03	0.95	0.73	1.02	0.90	0.95	0.61	0.73
Year	1924	1913	1911	1904	1925	1899	1926	1926	1918	1912	1911	1930
		ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ		ꓘ		TD	ꓘ
15 minutes	0.96	0.77	1.19	1.45	1.30	1.25	1.04	1.52	1.06	1.20	0.78	0.95
Year	1924	1913	1911	1904	1925	1922	1926	1926	1918	1912	1906	1930
		ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ			TD	TD	ꓘ
30 minutes	1.02	0.96	1.30	1.83	2.24	2.01	1.49	2.68	1.71	1.87	1.09	1.64
Year	1924	1913	1911	1904	1925	1922	1926	1926	1920	1909	1906	1930
		ꓘ	ꓘ	ꓘ	ꓘ		ꓘ			TD	TD	ꓘ
1 hour	1.63	2.29	1.38	1.98	2.78	2.64	2.00	4.30	2.12	3.35	1.71	2.38
Year	1899	1902	1905	1904	1929	1900	1916	1926	1920	1909	1906	1930
		ꓘ	ꓘ		ꓘ	ꓘ	ꓘ			TD	TD	ꓘ
2 hours	1.16	1.30	1.72	2.08	3.45	2.27	2.89	7.08	2.24	5.28	2.95	2.61
Year	1915	1913	1905	1919	1929	1912	1916	1926	1920	1909	1906	1930
		ꓘ	ꓘ				ꓘ		TD	TD	TD	
24 hours	3.97	2.99	4.52	3.23	5.83	5.48	7.46	8.32	11.95	11.23	8.86	3.93
Year	1879	1902	1905	1882	1904	1900	1916	1926	1919	1909	1906	1879
Month	7.65	7.19	6.89	4.99	13.01	12.97	10.89	15.83	17.29	19.77	10.82	10.03

Precipitations 24 hours, 60 years; 5 and 10 minutes and 1 hour, 34 years; 15 and 30 minutes and 2 hours, 27 years.

MIAMI

	January	February	March	April	May	June	July	August	September	October	November	December
	ꓘ	ꓘ		ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ		ꓘ	ꓘ
5 minutes	0.29	0.58	0.51	0.55	0.59	0.56	0.64	0.55	0.62	0.49	0.53	0.35
Year	1926	1922	1919	1914	1923	1929	1926	1930	1924	1922	1925	1918
	ꓘ	ꓘ		ꓘ	ꓘ	ꓘ	ꓘ	ꓘ	ꓘ		ꓘ	ꓘ
10 minutes	0.50	0.97	0.96	1.02	0.89	0.98	0.82	0.95	0.98	0.79	0.78	0.66
Year	1926	1922	1919	1914	1923	1929	1930	1930	1924	1922	1920	1918
	ꓘ	ꓘ		ꓘ		ꓘ	ꓘ	ꓘ	ꓘ	TD	ꓘ	ꓘ
15 minutes	0.71	1.19	1.34	1.32	1.29	1.31	1.12	1.06	1.32	1.08	1.09	0.88
Year	1926	1922	1919	1914	1913 ꓘ	1929	1930	1927	1924	1924	1925	1918
					1925 ꓘ							
	ꓘ	ꓘ		ꓘ	ꓘ	ꓘ	ꓘ	TD	ꓘ		ꓘ	ꓘ
30 minutes	1.13	1.74	2.26	1.83	2.15	1.76	1.82	1.53	1.86	1.83	2.07	1.20
Year	1926	1922	1919	1914	1925	1927	1926	1916	1914	1915	1925	1918
	ꓘ	ꓘ		ꓘ	ꓘ		ꓘ	TD	TD		ꓘ	
1 hour	1.76	2.45	2.82	2.05	2.96	2.74	2.68	2.83	2.77	2.69	3.50	1.93
Year	1926	1922	1919	1914	1925	1930	1926	1916	1928	1929	1925	1929
	ꓘ	ꓘ		ꓘ	ꓘ		ꓘ	TD	TD	TD	ꓘ	
2 hours	3.07	2.51	3.12	2.63	3.48	3.13	3.01	4.73	4.34	4.66	6.11	3.01
Year	1926	1922	1919	1914	1912	1930	1926	1916	1928	1924	1925	1929
	ꓘ	ꓘ		ꓘ	ꓘ		ꓘ	TD	TD	TD	ꓘ	
24 hours	6.69	2.51	9.04	3.22	9.36	7.15	4.90	6.12	10.58	9.53	15.10	5.31
Year	1926	1922	1919	1917	1930	1930	1926	1916	1929	1924	1925	1929
Month	7.93	5.91	9.74	10.75	18.66	25.34	15.22	13.71	20.35	27.86	17.72	12.08

Number of years of record for excessive precipitation, including greatest in 24 hours, 20. Number of years of record for greatest monthly amounts, 29 for Weather Bureau record; 37 for Weather Bureau and Army records.

Precipitation, record amounts—Continued

PENSACOLA

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.51	0.61	0.59	0.64	0.57	0.46	0.53	0.60	0.57	0.78	0.65	0.62
Year	1929	1912	1912	1912	1915	1916	1924	1915	1920	1909	1914	1916
10 minutes	0.71	0.94	0.97	1.15	1.01	0.79	0.87	1.13	0.99	1.55	1.16	0.92
Year	1918	1012	1912	1012	1915	1016	1908	1915	1920	1909	1914	1916
15 minutes	0.80	0.06	1.19	1.49	1.31	1.10	1.20	1.27	1.37	2.27	1.64	1.04
Year	1918	1912	1912	1912	1915	1916	1906	1915	1920	1909	1914	1916
30 minutes	1.07	1.30	1.55	2.10	1.07	1.72	2.17	1.90	* 2.25	3.63	2.20	1.17
Year	1903	1926	1912	1919	1915	1016	1907	1916	1906	1909	1914	1909
1 hour	1.64	1.48	3.01	3.10	2.43	2.23	3.33	3.01	3.73	4.27	3.17	1.59
Year	1903	1026	1912	1919	1915	1916	1907	1922	* 1906	1909	1003	1905
2 hours	2.58	1.84	3.98	4.38	2.62	2.43	3.96	4.71	* 6.14	4.82	5.03	2.15
Year	1903	1926	1012	1019	1015	1916	1907	1919	1906	1909	1903	1911
24 hours	3.52	5.05	8.32	8.91	5.63	10.70	5.01	9.60	8.56	7.30	7.66	4.32
Year	1881	1881	1913	1919	1915	1887	1896	1919	T.D. 1926	1923	1914	1911
1 month	9.97	12.53	13.37	13.90	0.92	14.11	17.90	18.52	18.65	14.66	14.82	11.06

* 2 days after tropical disturbance.

Precipitation, record amounts—Continued

TAMPA

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.47	0.66	0.55	0.52	0.70	1.00	0.54	0.59	1.05	0.57	0.44	0.42
Year	1904	1927	1900	1928	1930	1900	1920	1906	1924	1928	1903	1907
10 minutes	0.65	1.05	1.05	0.79	1.17	1.50	0.87	1.15	1.66	0.90	0.69	0.82
Year	1904	1927	1900	1921	1930	1900	1020	1898	1924	1928	1911	1907
15 minutes	0.73	1.26	1.40	0.98	1.58	1.90	1.12	1.60	2.03	0.08	0.82	0.94
Year	1909	1927	1900	1921	1930	1900	1910	1898	1924	1928	1911	1907
30 minutes	0.93	1.06	1.50	1.73	2.00	2.45	1.86	2.72	2.44	1.26	1.31	1.33
Year	1912	1927	1900	1920	1930	1900	1920	1925	1924	1902	1925	1907
1 hour	1.28	2.17	1.65	2.56	2.74	3.65	2.61	4.01	2.76	1.52	1.55	1.98
Year	1904	1927	1900	1920	1902	1930	1920	1925	1924	1923	1925	1907
2 hours	1.60	2.40	2.49	2.76	3.04	4.46	2.84	4.59	3.22	2.21	2.04	2.76
Year	1904	1927	1930	1920	1902	1930	1920	1925	1907	1923	1925	1907
24 hours	3.58	4.06	5.62	[1] 2.94	3.55	5.54	5.53	5.04	6.56	T.D. 6.48	4.18	3.93
Year	1914	1902	1030	1930	1923	1909	1925	1915	1897	1921	1916	1907
Month	6.73	6.27	9.87	8.04	0.41	13.47	15.53	17.83	18.93	10.33	4.85	7.36

[1] Amount exceeded this year, 1931, —4.25.

EDWARD H. SMITH ON THE SCIENTIFIC RESULTS OF THE MARION EXPEDITION OF 1928, TO DAVIS STRAIT AND BAFFIN LAND

By W. F. McDonald

[Weather Bureau, Washington, December, 1931]

Since its establishment in 1913 as a result of the *Titanic* disaster, the international ice patrol has been collecting scientific data on the oceanography of the ice regions of the North Atlantic as an adjunct to its primary work of scouting for bergs and warning shipping of dangerous ice movements.

Lieut. Edward H. Smith has for more than 10 years been concerned with the scientific aspects of the ice-patrol work. In his latest monograph on scientific results of the intensive oceanographical survey conducted by the Coast Guard cutter *Marion* during the 1928 patrol season, he sums up not only the fruits of his own extensive observations and researches but also includes a comprehensive survey of world literature on the subject of polar ice and ice movements.

The work, published as Part 3 of Coast Guard Bulletin No. 19, includes original contributions by Lieutenant Smith toward the solution of such complex questions as the following: In what manner does ice from the Polar Basin, Baffin Bay, and Hudson Bay, contribute to supply the North Atlantic? What is the annual variation in ice limits and number of icebergs? In what proportions do wind and current enter to control the drift of icebergs? Is the effect of ice melting in northern waters a factor of importance in the main system of oceanic circulations? What meteorological and other factors govern the probable seasonal prevalence of ice along the trans-Atlantic steamer routes?

The chief source of the icebergs that drift to the steamer lanes is conclusively demonstrated to be the great Greenland glaciers of the Baffin Bay region. Major productivity of bergs is confined to the 300-mile stretch of west Greenland coast, central on the seventieth parallel of latitude, and comprising Northeast and Disko Bays, but a lag of some months and in some cases years intervenes between the calving of bergs and their final disappearance in the waters off Newfoundland. The character of the weather during the life of a berg has much to do with determining the route over which it drifts, and also its rate of melting.

Lieutenant Smith demonstrates that the quantity and disposition of the great sheets of relatively thin ice, classed as "pack ice" is a most important factor in the number of bergs which reach the vicinity of the steamer lanes. Sheet ice forms annually to an estimated average thickness of six feet over an area believed to be between 400,000 and 500,000 square miles contributory to the northwestern Atlantic. The amount of pack ice formed depends directly upon the severity of the winter temperatures, and perhaps less directly upon other meteorological conditions (such as storminess) which affect the set of the circulations and the mixing of water masses.

Being sheetlike in structure, pack ice responds readily in its movement to wind; in this respect it is perhaps the most responsive of all oceanographic phenomena to meteorological conditions.

Icebergs are not so responsive to wind, because the exposed portion is only a small fraction of the total mass. However, the shape of the berg appears to be quite important in this connection since its manner of drift seems to depend on the ratio of extreme height above water to the maximum depth of immersion rather than upon the relative masses above and below the water line.

The average ratio of height above water to draft in the case of the usual type of Greenland bergs is reported to be much less than commonly supposed. The ratio of 1 to 3 is common in the earlier stages and as low as 1 to 1 has been measured in certain horned or winged disintegration forms.

It is apparent from these and other analogous facts that in general the drift of icebergs is more subject to the influence of sea currents at some depth than to the pressure of wind. Smith adduces quantitative data in respect to the relative importance of wind and current

and his conclusion is best stated in his own language, as follows: "The deeper draft bergs common to Baffin Bay are moved only 4 miles a day by wind, force 6 to 7. In the case of the deeper bergs drifting within the bounds of an ocean current such as the Labrador current, small influences due to frequently shifting winds are masked by simultaneous movements imparted by the much steadier and more enduring slope current."

The variation in drift, to the right of the wind direction, under the Ekman effect, is stressed, and it is stated that "During a period of even moderate to fresh winds the shoaler berg will drift about 14° to the right of the heavier ones in 24 hours and leave the latter some 4 miles astern, the bergs alternately separating and congregating with the play of the winds." This shows conclusively the major influence of the stable ocean currents rather than the winds, in producing the steady travel of bergs over long periods of time.

Strong evidence supports the conclusion that the amount of pack ice moving down the Labrador coast to the Newfoundland banks is a major factor in the arrival of icebergs in the same vicinity. It seems that the ice pack covering the shallower coastal waters fends off the icebergs and keeps them moving southward; contrariwise, with coastal waters free from pack there is stranding and melting of bergs before they attain the region of the Grand Banks. The year 1928 was marked by a great scarcity of pack ice and also of bergs off Newfoundland, while a close estimate in that year indicated that over 700 icebergs were stranded between Belle Isle and Hudson Strait.

Significant correlation is found between the winter atmospheric pressure gradient (December to March), Ivigtut to Belle Isle, and the spring crop of icebergs south of Newfoundland. Forty-seven years of records enter into the computation. Other significant meteorological factors were found, including mainly the pressure anomaly over Iceland, December to March, and the pressure gradient, October to January, between Iceland and Bergen. The combination of these factors indicates that an excess of pressure in winter over Iceland and southern Greenland, especially in December and January, is unfavorable to the movement of icebergs southward toward the Grand Banks and the steamer lanes in the next spring; the opposite relation is unmistakable in its correlation with a greater number of bergs than normal, but shows a smaller correlation coefficient than that between excessive pressure anomalies and poor iceberg years. This indicates the influence of other more obscure factors, such as variations in air and water temperatures in the far north; variations in precipitation, and perhaps sporadic phenomena such as loosening of ice jams in the Arctic Archipelago or Smith Sound, in releasing unusual quantities of bergs.

The *Marion* oceanographic program included a number of surveys to secure basic data for estimation of the dynamic gradients underlying current drifts and variations. The results are of considerable interest to the meteorologist, in revealing the presence of a dynamic cyclone in the sea where the Labrador current meets the Gulf Stream near the "Tail of the Grand Banks," about 49° W. longitude, and 42° N. latitude.

As might be expected this cyclonic circulation in the ocean currents is of much smaller extent though more persistent than the usual atmospheric cyclone. In discussing this peculiar local movement, which, it is worth emphasizing, occurs in the region where the temperature gradient is at a maximum between the cold outflow from the Labrador current, and the warm flow of the Gulf Stream, Smith says:

> This "low," covering an area of over 2,000 square miles, was first discovered by chance in 1921 by following an iceberg as it made the circuit. In 1926 the "low," apparently similar in character to an atmospheric cyclonic depression, was accurately charted by several successive dynamic surveys, prevailing throughout the season. It was present also in April, 1927, but disappeared early that May * * *. In general, the agreement between the berg tracks that have actually been followed and the gradient currents for the same periods, respectively, is so close as to indicate that dynamic projections of this sort may be used as a basis for predicting the tracks that individual bergs are most likely to follow. * * *
>
> The current maps obtained by dynamic surveys have been found to remain reliable for a period of 7 to 15 days around the Grand Banks. Minor fluctuations of short duration have often been observed, however, especially along the boundary of mixed waters and the Gulf Stream. Such swirls or vortices appear to be secondary superficial tongues 5 to 10 miles in width and several times that in length and the tracks of icebergs, especially the small shallow-draft ones, are often modified by such departures.
>
> Occasionally icebergs survive relatively long periods, even when floating in Atlantic Ocean water of high temperature, and they may then make phenomenal journeys. * * * These drifts, however, do not indicate a direct extension of the Labrador current into low latitudes but simply that the bergs in question have been caught up in oceanic vortices that are continually forming over the Atlantic Basin, in which the ice is borne southward instead of following the normal drift. * * * As a matter of fact, it is unusual for a berg to drift south of the fortieth parallel of latitude in the western North Atlantic, the record for the past 20 years showing only 1 such occurrence every 1 to 3 years.

In a footnote, the author adds: "It has already been pointed out that the outlet for icebergs departing on extra southerly drifts is noticeably confined between meridians 46 to 50, almost directly south of the Grand Banks."

The observations of icebergs and ice-pack movement past Newfoundland and along the Grand Banks rather conclusively disprove the existence of a branch of the Labrador current setting steadily westward or southwestward from Cape Race. The Gulf of St. Lawrence does, however, discharge pack ice and icy waters past Nova Scotia, and the supply of cold water from this source, plus the natural cooling processes, seem ample to account for the maintenance of a cold zone between the Gulf Stream and the New England coast.

The study concludes with a most interesting and valuable discussion of the effect of northern ice on the temperature and circulation of the waters of the North Atlantic. Beginning with the estimate that more than 1,000 cubic miles of ice are annually transformed from solid to liquid in the northern North Atlantic along a front from Spitzbergen to Labrador, there is an examination of the propositions, which some students have advanced, that the heat required to melt this enormous quantity of ice produces the chilling effect "which initiates great downpourings of cold bottom waters" and thus serves as the "main energizing agent responsible for the Atlantic circulation." Lieutenant Smith examines these propositions with quantitative estimates of the factors involved.

Of the sea ice present in the Davis Strait-Baffin Bay region (which embodies the major iceberg production in the northern hemisphere) the glacial ice comprising the bergs is only 2 per cent. The remainder represents ice frozen from sea water, in which case the release of latent heat "produces a material retardation in the freezing

process, and this phenomenon, moreover, is of such magnitude in the polar regions that it tends to stabilize the seasonal fluctuations."

It is clear from the small ratio of icebergs to total ice, that the discharge of glacial ice is of no practical moment in the cooling of sea water. Further, the fact that in vertical dimension, total sea ice is only about one-thousandth of the mean depth of the Atlantic shows how superficial the ice processes must be. Melting produces relatively light thaw water, which stratifies stably at the surface and creates a situation in which solar warming of the summer season is largely accumulated as a heat reserve in the upper layer of only 20 to 40 meters depth, underlaid by a tremendous mass of cold water representing the net accumulations from winter cooling by radiation, within the great area of the Polar Basin and its adjacent waters.

The radiation absorbed in the areas of open water, which is thus largely confined to the shallow top layer, is readily lost, with the onset of winter, and is not adequately compensated by the latent heat released by freezing of new ice. These and other considerations lead to a quantitative estimate that only about 10 per cent of the total cooling received by the North Atlantic in the southward discharge of cold currents can be attributed to the cooling effect of ice melting. The final summations are best stated in the author's own words, as follows:

Obviously, the low temperature character of the Labrador and east Greenland currents is not due to the melting ice with which these streams are charged in spring and summer. These ocean currents are cold because of the small amount of absorption of solar radiation at the earth's surface in the polar regions. * * *

It is interesting to note in the quantitative treatment of these northern seas phenomena that the cooling factors, viz, chilling by the winter atmosphere, ice melting, snowfall, and evaporation, when totaled, outweigh the solar warming of summer. * * * The great major effect therefore tending to maintain more or less of a constant counterbalance over a long period is the warm currents from the Tropics. * * *

Perhaps it is because the ice catches the eye and the imagination more than do the coastal water masses with which it is ordinarily associated that its relative importance in the picture of oceanographic circulation has been overemphasized. The regional difference of density between coastal and oceanic waters is the main spring for the convectional currents. The winds also, by their direct frictional effect, combined with the presence of the coast lines or other hindrances, develop significant slope currents. The transition zones, i. e., the continental edges, and the (submarine) ridges, mark the belts of greatest energy, and in the sea energy is synonomous with current.

Ice melting over the North American and east Greenland shelves helps to accentuate the contrasts between coastal and oceanic waters, thereby intensifying the currents, but emphatically it is not the main cause of propulsion nor is it even a necessary attribute thereof.

The bulletin is amply illustrated with diagrams, charts, and pictures but the lack of a good map of the north polar regions, fully identifying the geographic features to which frequent and repeated reference is made, is the one point of inadequacy found in this interesting and valuable contribution to oceanography.

CLOUD FLIGHTS [1]

By A. LOHR

[Hamburg, Germany]

[Translated by Eric R. Miller and abstracted by L. T. Samuels]

The daily airplane observation flights made by the Deutsche Seewarte at the Fuhlsbüttel airport have been classified and those made at times when the airplane passed through a solid cloud layer, i. e., when during both the ascent and the descent the earth was entirely cut off from view, have been segregated. The percentages of such flights of the total during 1928 and 1929 were 46 and 44, respectively.

The following features are mentioned:

If the lower boundary of a solid cloud sheet consists of Fr. St. or Fr. Nb., then there is no great danger in emerging from the cloud in descent as the turbulence existing near the ground, indicated by the Fr. St. and Fr. Nb., results in the partial dissipation of the lower boundary of low cloud forms. The Fr. St. or Fr. Nb. very frequently extends to within 100 meters of the ground and has a vertical thickness of 100 to 300 meters. With Nb. there follows immediately the transition to the continuous main cloud sheet, whereas with St. there is often observed a separate thick, clear, intermediate stratum between the Fr. St. and the dense continuous St. A far more dangerous condition to aviation occurs when the Fr. St. or Fr. Nb., stratum is absent and the base of the main cloud sheet is only 100 to 150 meters above ground. In such cases the cloud layer may often reach the ground in some places.

The form of the upper surface of the cloud sheet is varied. On many days it appears like an entirely plane surface. At such times a strong temperature inversion always exists at its level. When a heavy accumulation of haze prevails over the upper cloud surface, then from a greater height the cloud layer appears as an absolutely smooth surface. Occasionally the upper surface is slightly rippled and shows an irregular structure, while at other times it is regularly waved. The wave crests may extend lengthwise for a kilometer but are never very high. All of the types of clouds thus far referred to are an indication of little or no vertical motion within the layer.

Turbulence rolls such as occur in a St. Cu. layer are fundamentally different from the above-mentioned wave structure. In summer, it frequently happens that a horizontal upper surface is overtopped by single Cu. heads which indicate local and narrowly limited overheating. Such Cu. forms are frequently surrounded by cloud-free holes in which descending air creates rather strong "falling" bumpiness.

The cumuli of convection exhibit a more stupendous form than the cumuli of turbulence. The former rise most steeply into the heavens and when illuminated by the sun conjure up marvelous pictures by their rugged lights and shadows. From them, occasionally, thunderheads rise upward to 6,000 meters altitude. The strong bumpiness around the edge of such thunderheads is well known. Flying through them can not be sufficiently warned against. Within such clouds vertical gusts reaching from 10 to 15 meters per second are encountered while below an ordinary cumulus these velocities usually reach only 2 to 4 meters per second, the latter being very successfully employed in early gliding experiments.

In connection with the vertical currents in upwelling Cu. heads there occur the "caps" over the Cu., the latter being composed mostly of ice particles. Often the raised St. layers that are penetrated by the thunderhead spread

[1] Meteorologische Zeitschrift, September, 1930.

out at the flank of the towering head and may rise upward over the latter. At times the veil-like St. may be elevated throughout an extensive region by the underlying turbulent stratum so that it has the appearance from a greater height of a smooth stratus sheet in which the Cu. are embedded as soft fountain-like forms.

In airplane observations it is often necessary to penetrate a uniformly dense, formless cloud mass more than 4,000 meters thick, when frequently it is impossible to see the tips of the wings of the airplane. An extreme case of this kind occurred on January 2, 1930, when upon descending, the airplane entered the cloud at 5,000 meters elevation and emerged from it at about 50 meters above the ground. Such enormous cloud formations appear nearly always to be associated with the passage of a "wind convergence."

During one flight to 7,000 meters elevation, an opportunity was afforded to observe Ci. at close range. The impression obtained was that massive fall-stripes (Fallstreifen) are formed from Ci. clouds and that they (Ci.) are composed of ice crystals.

During a night flight in the autumn of 1928 the gleam of light from the city appeared on the cloud surface with great clearness.

It was occasionally found that the starting of the airplane motor caused the "ripping open of a lane" in a ground fog.

In Cu. of turbulence it was found that the rows ran mostly in long streaks some hundreds of meters apart, parallel to one another, nearly in the direction of the wind. These rows often exhibited cross-rippling.

Although flights within or under the "squall roll" are to be avoided, some flights were started shortly before an oncoming squall. It was found that over a breadth of 3 to 5 kilometers in front of the "squall roll" there exists a strong vertical bumpiness, which disappears, however, directly above the "squall roll." The area behind the "squall head" is, likewise, free from bumpiness.

It was found to be very difficult to estimate correctly the height of clouds from the ground and to judge their vertical extent from their appearance. In a uniform stratus layer, the visibility horizontally and vertically downward sometimes vanishes immediately on entering the cloud, while at other times the ground is visible for a long time through the cloud mass. This may be due to the size and number of the cloud droplets. From a study of fog, being made at the Deutsche Seewarte, it has been found that fog droplets may be regarded as smooth, opaque little disks and, therefore the visibility varies according to the number and radius of the droplets, with the same vapor content of the air.[2]

[2] A drop of any given radius is equivalent in mass to 8 drops of half that radius, while its equatorial cross section is half the sum of the similar cross sections of the 8 small drops. Hence the interference of the 1 large drop, to a beam of light is just half that of the equivalent 8, except in so far as 2 or more of the latter may chance to be along the same line of sight. Clearly then, for any given mass of water in droplet form (fog or cloud) betweeen observer and object, the visibility increases roughly as the radius of the droplets.—Ed.

SHOWER AND DRIZZLE

By W. J. Humphreys

Of course everyone knows what a shower is and what a drizzle is too, until he tries to define them. For our present purpose, which is to consider how each is produced, and what therefore under given circumstances it probably signifies, we shall define a shower as a rain of brief duration of medium-sized to large drops; and a drizzle as a very light rain, usually more or less persistent, of quite small drops. If the drops are as much as one twenty-fifth of an inch in diameter, or larger, surely they do not constitute a drizzle, but rain, and fall with a velocity of, roughly, 10 to 25 feet per second, as determined by the size of the drop and density of the air through which they are falling. They can not fall faster than around 25 feet per second because if, and as soon as, through coalescence or otherwise, they become large enough to fall with a greater speed they at once are torn to pieces by the drag of the air through which they are passing. But the rate of fall, whatever it be, is of course, with reference to the air and therefore not at all necessarily the speed of approach toward the surface of the earth. The two velocities, that is, the rate of fall through the air and the rate of approach toward the surface of the earth, are the same only when there is no vertical movement of the air through which the drops are falling. Wherever, then, the upbrush of the air is equal to, or greater than, the rate of fall of the drops through such atmosphere, that particular precipitation can not approach closer to, much less reach, the surface. Of course the greater the height and, consequently, the rarer the air, the greater its upward velocity must be, and in proportion to the decrease of density, to sustain drops of a given size.

Only the largest possible raindrop, one fifth of an inch in diameter, falls through still air of average sea level density at the uniform rate of 25 feet per second. The drops of a moderate rain, as that term is commonly used, having a diameter of, roughly, one twenty-fifth of an inch, have a velocity of fall of about 12 feet per second. Drizzle drops, so small that it would take about 125 of them to span an inch, fall only some two and a quarter feet per second, while cloud droplets, 1,200 of which would stretch barely one inch, fall only one twenty-fifth of a foot, or thereabouts, per second, or 144 feet in the course of an hour.

From the foregoing it is clear that for each given velocity of ascent of the air there is a corresponding minimum size of raindrop that can get through it to lower levels. Smaller drops can not fall while the appreciably larger ones must and do. Hence ascending air carries cloud droplets up and keeps them up until by further condensation, coalescence, or both together, they have grown large enough to overcome the lift of the rising air, whereupon, but *not* until they have so grown, they fall to the earth.

If appreciably rising air carries cloud droplets up, as it certainly does, one asks then how it is that the cloud itself, base and all, is not lifted to greater heights. The explanation is that while the individual droplets are lifted to greater levels fresh cloud is continuously formed in the uprising air as soon as, through expansion, incident to increase of height, it has cooled to its dew point, or saturation temperature. The individual particles are carried up, but continuously replaced by freshly-formed droplets at the same cloudbase level. And if the ascent is gentle the droplets soon are evaporated a little way above in the drier air and no rain is formed.

A drizzle, then, or very gentle rain of quite small drops, occurs only where there is little or no ascent of the air—two and a half feet per second at most. A shower, on the other hand, which consists of relatively large drops, requires for its production vertical convection of consider-

able strength. Furthermore, the shower covers, at any instant, only a rather limited region because the air obviously can not be going up everywhere at the same time over a wide area. Hence also it is of short duration. A persistent rain of largish drops can happen only where the cause of the convection, such as a mountain across the path of the wind, is enduring and fixed in position. But such a rain is not a shower.

So much for the difference between the ways in which drizzles and showers are formed. It will be interesting now to inquire what circumstances lead to vertical convections of the air such as give showers, and what to drizzle rains in which clearly there is but little or no convection. Whether or not marked convection will develop depends on the vertical distribution of temperature, mainly, and to some extent also on that of water vapor, for increase of humidity decreases the density of the air just as does increase of temperature. Convection not only can, but must, ensue wherever and whenever the surface of the earth is considerably warmed (by sunshine chiefly) since it in turn then correspondingly heats the lower air which thereupon expands and becomes lighter. This is the origin of the heat thunderstorm so common in the Tropics and adjacent regions. Where condensation occurs in such cases latent heat of vaporization is rendered sensible and the convection thereby still further accentuated, as is evident from the great height to which the cumulus cloud often towers.

Another way by which the vertical contrast of temperature essential to convection is established is by the importation of colder air above. Still another is the wedging in of cold air under warm air. Both of these ways, overrunning and underrunning, occur along the cold front, or windshift line, and often in such vigorous manner as to produce severe squalls. Still another way of inducing vertical convection, commonly moderate and therefore productive usually of rather gentle showers, is by the gradual heating of the under layer or portion of cool air as it drifts over a surface that becomes increasingly warm with the distance traveled. This applies perfectly to a broad deep mass of air of polar origin drifting equatorward over an ocean. Here, and often on land as well, the showers are indicative of the origin (polar) of the air in which they are occurring.

On the other hand, the lower portion of a current of air of tropical origin moving over the ocean, say, or land either, to higher latitudes, tends to become progressively colder and colder, and thereby so stable that local convection in it is quite impossible. After a time the dew point may be passed with the formation of fog and low cloud out of which a drizzle, light to heavy, may fall, but never a shower, there being no vertical convection, except that small amount incident to the turbulence caused by surface friction.

We therefore are assured that such rains as occur within polar air as it advances equatorward are quite likely to be of the shower type and, conversely, that showers often are convincing evidence that the passing air is of polar origin. Similarly, tropical air moving poleward may afford a drizzle long before a mountain, or a barrier of cold air, is encountered. Also a drizzle is evidence of tropical air on its way to higher latitudes.

Showers evidence the presence of marked vertical convection; drizzle proves the absence of such convection. Showers often indicate the equatorward passing of polar air; drizzle the presence of poleward-moving tropical air. Thus shower and drizzle are well nigh rain extremes—in size of drops, rate of precipitation, nature of origin, and their meteorological significance.

METEOROLOGY AND THE FOREST FIRE PROBLEM

By S. B. SHOW

[United States Forest Service, Washington, D. C.]

Foresters have always recognized the importance of the relationship between weather and forest fires in the West. For a number of years after organized fire suppression was instituted, the relative importance of the various weather factors upon fire suppression during the fire season was unknown, or at best, guessed at. Even in these early days it was generally recognized that occasionally in every fire season there occurred short periods of one or several days when the forest cover was unusually inflammable and at times seemed almost explosive. These periods frequently produced greater damage, burned over area, and suppression costs than the remaining 95 per cent of the fire season. This being so, it was essential that attempts be made to determine the factors that brought about these dangerous periods. It was recognized, of course, that abnormal weather conditions were responsible for these periods, but which of the meteorological conditions were most responsible was unknown to foresters. Obviously, the study of the influencing factors was the first needed step to be undertaken in the solution of this problem.

Accordingly, from 1915 to 1925 this phase of the problem was the subject of several independent studies by various members of the Forest Service in the important fire regions, aiming to supplement the work of the Weather Bureau. The main objective was the determination of the principal climatic causes of the sudden changes in the inflammability of forest fuels.

It was found that during the fire season, for some of th most inflammable of our forest types, wind velocity an direction and relative humidity are the most importan meteorological factors affecting the spread of a fire With wind remaining the same, relative humidity is a exceedingly important factor in controlling the size o fires; the lower the humidity, the greater the size. Simi larly, with relative humidity constant, there is an increas in size of fires as the wind velocity increases. The critica periods of explosive inflammability always occur whe very low relative humidity occurs together with a hig wind velocity. Neither low relative humidity nor hig wind velocity alone has resulted in such a high rate o spread as the combination of these two factors. Th effect of changes in wind direction on fire control endeavo is obvious.

The prediction of these periods and of their duration i of utmost importance to those engaged in forest fir control. The Weather Bureau began its fire-weathe warning service in 1916 in California, and has, year b year, consistently enlarged and improved this servic In 1926 a special fire weather official was assigned to th California district which coincides with Region 5 of th Forest Service. Since that time substantial progress ha been made in laying the ground work for systemati fire weather forecasting and increasingly valuable info mation has been furnished the field officers of the protec tion agencies. Many special observation points ar

now supplied with instruments, owned and installed by the Weather Bureau. Most of these special stations are either ranger headquarters or forest lookout stations, and the forest personnel act as observers.

The fire-weather forecasting service furnished in California can be divided broadly into two classes, one of these services being the telegraphic general fire warning forecasts which are sent out in advance of dangerous fire weather or anticipated lightning storms. These messages emanate from the San Francisco office of the Weather Bureau and are sent to designated fire-fighting agencies in those parts of the State affected. For convenience in this work the Weather Bureau has divided the State into 11 forecasting areas, designated by locality, such as North Coast, Siskiyou, Plateau, North Sierra, etc. The field personnel of the Forest Service have learned from experience to depend upon the reliability of these warnings. When one of these messages is received the tendency is for each man to be more alert; the lookout scans the country more closely, the fireman is on the qui vive, the fire dispatcher makes doubly certain of his sources of man power and equipment, the Ranger stays in closer touch with his protective organization. If a fire warning message comes over a week-end or holiday, often emergency men are hired as an additional preventive measure. If these messages come during the time a fire is burning, very often plans are changed accordingly, especially if the fire is not yet under control. These fire warnings are a very important aid in our fire control.

While such general, more or less broadcast warnings were of value, the need was apparent for more localized forecasts. Such a need is particularly great where there are large going fires. Accordingly, in 1929, through a cooperative agreement between the State, Weather Bureau, and the Forest Service, a portable forecasting unit was set up. This unit consisted of a truck, completely equipped with meteorological instruments and a radio receiving set. The fire weather official was in charge of the unit and had, as an assistant, a radio operator. This unit operated in 1929 and 1930, and is on the job again this season. It is scheduled to visit every national forest throughout the State each season, as well as spending a proportionate amount of time in each State fire district. Contacts are made with Forest Service and State personnel and weather stations maintained by these agencies are checked and inspected. Daily forecasts are made from weather information received over the radio and through observation made by the fire weather officials. These forecasts are made for the locality in which the truck is stationed at the time. A central dispatching agency at the regional Forest Service office is kept informed of the location of the unit at all times, and it is dispatched whenever practicable to going fires anywhere in California.

So far, there have not been as many opportunities as was originally expected to make use of the unit on going fires. On those accasions, however, when forecasts have been given on going fires, the reports from the field as to its value have been most encouraging. For example, on one very large fire, in very inaccessible country, due to forecasts of favorable weather conditions for the following day, an order for a large number of men and additional supplies and equipment was canceled, and the Government saved a very considerable sum of money. Certainly, the value of localized fire warning service has been demonstrated through the performance of this portable forecasting unit. An extension of this localized service, together with a continuance of the constantly improving general fire weather warning forecasts, offers a major opportunity for improving systematic fire protection in California.

THE PROBABLE VALUES OF SEASONAL RAINFALL IN LOS ANGELES FROM 1850 TO 1877

By Charles C. Conroy

[Author's Abstract]

Some years ago the writer began to collect material bearing upon the rainfall of the Los Angeles area prior to the establishment of the United States Signal Service office in that city on July 1, 1877. This material was found in private journals and diaries, in printed accounts, and, after 1854, in the files of Los Angeles newspapers. These last yielded an abundance of information, and the author was finally enabled to discover practically every day on which rain had fallen over the entire period.

These daily statements were translated into numerical values by comparison with estimates based upon Weather Bureau measurements of rainfall for similarly described days after July 1, 1877. For example, it was found that days on which rain was said to have fallen steadily but not heavily throughout the day, when checked by the measurements, had an average precipitation of 1.32 inches. Using this method for other descriptions, it was possible to build up a table of daily estimates for the entire period 1850–1877. Monthly and seasonal results followed as a matter of course.

The conclusions were then checked by reference to the recorded measurements of rainfall at San Francisco and San Diego for the same period, a ratio having been worked out for two 10-year periods—one dry and one wet—from the records of all three stations subsequent to July 1, 1877. The use of this method of checking required great care, since there was sometimes an inversion of monthly or even seasonal values, San Diego receiving more rain than San Francisco. Fortunately the local accounts prior to 1877 were in almost all cases so definite that estimates could be made with considerable assurance of their approximate accuracy.

Further checking was done for the period 1871–1877 through comparisons of daily barometric readings at San Francisco and San Diego. For this same period a series of measurements made at Los Angeles by proper exposure of a gage was also found, as were also similar measurements for a single year in the fifties.

No rigid mathematical investigation was possible by these means, but it is believed that the evaluated amounts have a margin of error under 15 per cent.

Since the results cover 27 years, the subsequent records of the Los Angeles Weather Bureau office from 1877 to date may be divided exactly into two equal periods.

The mean seasonal rainfall for the three is found to be as follows:

	Inches
1850–1877	14.09
1877–1904	15.30
1904–1931	14.53

The driest winter in the entire series was that of 1862–63, with an estimated rainfall of 4.30 inches; the wettest, that of 1883–84, with a measured rainfall of 38.18 inches.

In the first of these 27-year periods there was a relatively wet series of seasons from 1851 to 1862; two disastrously dry seasons followed; then came another relatively wet series ending on June 30, 1869, and finally a dry series ending on June 30, 1877.

The individual seasonal estimates are as follows:

	Inches		Inches
1850–51	8.60	1864–65	13.60
1851–52	15.30	1865–66	15.40
1852–53	17.20	1866–67	19.80
1853–54	15.50	1867–68	23.50
1854–55	18.00	1868–69	15.30
1855–56	12.60	1869–70	7.20
1856–57	5.90	1870–71	6.30
1857–58	18.50	1871–72	12.80
1858–59	10.20	1872–73	9.60
1859–60	18.60	1873–74	21.20
1860–61	13.70	1874–75	12.40
1861–62	32.00	1875–76	21.80
1862–63	4.50	1876–77	5.30
1863–64	6.20		

The author believes that the influence of the Brückner cycle and the double Wolf cycle are clearly discernible in the estimates made for the period 1850–1877, and that the results seem to forecast the early beginning of a wetter rainfall régime in this region.

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING NOVEMBER, 1931

By HERBERT H. KIMBALL, in charge, solar radiation investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged above the normal values for November at Madison and slightly below normal at Washington and Lincoln

Table 2 shows an excess in the total solar radiation received on a horizontal surface at Chicago, New York, and Fresno as compared with November normals for the respective stations; close to normal at Pittsburgh, La Jolla, and Miami; and a deficit at Washington, Madison, Lincoln, Gainesville, and Twin Falls.

Skylight polarization measurements made on 4 days at Washington give 60 for the mean percentage of polarization, with a maximum of 66 per cent on the twenty-fourth. At Madison, polarization measurements made on 4 days give a mean of 72 per cent with a maximum of 75 per cent on the fifth. These are above the corresponding averages for each station in November.

Data received too late to be included in Table 2 for October.

Gainesville, Fla., weeks beginning, October	1	8	15	[illegible]
Weekly averages of solar radiation, gr. cal. min. cm^{2}	307	308	403	3[illegible]
Departures from normal values	−92	−88	−8	−[illegible]

TABLE 1.—*Solar radiation intensities during November, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	c.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	c.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
ov. 3	5.56				1.24						3.96
ov. 4	5.16	0.87	1.07	1.24	1.36	1.49	1.34	1.15	1.00	0.85	3.45
ov. 5	5.36			1.01	1.25				0.84		4.17
ov. 10	6.27		0.38	0.51	0.79		0.80				7.57
ov. 23	8.81			0.78	1.12			0.95	0.81	0.66	12.24
ov. 24	8.81			0.92	1.26		1.28				9.14
Means		(0.87)	(0.72)	0.89	1.17	(1.49)	1.14	(1.05)	(0.88)	(0.76)	
Departures		+0.11	−0.14	−0.11	−0.01		−0.03	+0.06	+0.04	+0.03	

Madison, Wis.

ov. 3	6.76							1.24			5.56
ov. 4	3.99	0.92	1.08	1.22	1.36						3.30
ov. 5	3.63	0.98	1.11	1.31	1.42						3.81
ov. 13	4.37		1.06	1.14	1.35						3.81
ov. 18	4.57		0.96	1.10	1.32						5.36
ov. 22	4.95				1.19						7.29
Means		(0.95)	1.05	1.19	1.33			(1.24)			
Departures		+0.07	+0.04	+0.04	+0.04			+0.10			

Lincoln, Nebr.

ov. 2	4.95	0.83	0.96	1.11	1.31	1.54	1.31	1.13	1.00	0.86	6.76
ov. 4	3.81		0.68	0.89	1.26						3.81
ov. 5	3.81							1.27	1.14	0.99	2.87
ov. 6	5.16		1.00	1.08	1.24						3.99
ov. 7	4.75	0.78	0.86	0.99							6.50
ov. 18	2.49		1.00	1.11							5.79
ov. 24	2.87	1.03	1.15								2.36
ov. 25		0.93	1.00	1.16	1.38			1.21	1.10		3.30
Means		0.89	0.95	1.06	1.30		(1.31)	1.20	1.08	(0.92)	
Departures		−0.01	−0.07	−0.11	−0.04		−0.04	+0.01	+0.04	±0.00	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

AVERAGE DAILY TOTALS

/eck beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	Fairbanks
1931	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
ct. 29	185	167	212	149	188	224	156	418	353	293	278	12
ov. 5	222	178	225	162	235	187	161	295	299	216	375	10
ov. 12	165	113	179	124	97	172	122	244	251	268	391	10
ov. 19	182	78	106	112	117	175	119	254	254	301	359	6
ov. 26	97	137	138	98	89	184	61	162	207	231	328	3
	DEPARTURES FROM WEEKLY NORMALS											
ct. 29	−48	−21	−26	+9	+13	−55	+3	+74	+45	+22	+7	
ov. 5	−4	+9	−4	+42	+86	−41	+25	−9	+23	−38	+29	
ov. 12	−20	−23	−20	+21	−27	−13	−2	−44	+3	+13	−34	
ov. 19	+4	−50	−91	+18	+8	+7	+1	−6	+24	+32	+30	
ov. 26	−59	+11	−44	+16	−8	+24	−38	−73	+2	−40	−17	
ccumulated departures on Dec. 2	−1,577	+2,793	+882	+2,569	+2,394	−5,368	−1,478		+1,946			

POSITIONS AND AREAS OF SUN SPOTS, NOVEMBER, 1931

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnisbed by Naval Observatory, in cooperation with Harvard, Yerkes Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. Tbe total area, including spots and groups, is given for eacb day in the last column.]

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	H	m	°	°	°			
Nov. 1 (Naval Observatory)	11	38	No spots					
Nov. 2 (Yerkes Observatory)	14	4	No spots					
Nov. 3 (Naval Observatory)	10	17	No spots					
Nov. 4 (Naval Observatory)	11	57	−39.0	222.4	−0.5		40	
			+56.0	317.4	+8.0		46	86
Nov. 5 (Naval Observatory)	10	10	−26.0	223.2	−0.5		93	
			+68.0	317.2	+7.0		154	247
Nov. 6 (Naval Observatory)	10	36	−12.5	223.3	−0.5		108	
			+80.0	315.8	+8.0		463	571
Nov. 7 (Naval Observatory)	10	23	+2.0	224.7	−0.5		93	93
Nov. 8 (Naval Observatory	10	58	+16.0	225.2	−0.5		77	77
Nov. 9 (Naval Observatory)	10	51	+26.5	222.6	−1.0		25	25
Nov. 10 (Naval Observatory	11	29	No spots					
Nov. 11 (Naval Observatory)	11	49	No spots					
Nov. 12 (Naval Ohservatory	10	32	No spots					
Nov. 13 (Naval Observatory)	12	55	No spots					
Nov. 14 (Naval Observatory)	13	34	No spots					
Nov. 15 (Naval Observatory)	10	57	No spots					
Nov. 16 (Naval Observatory)	10	13	No spots					
Nov. 17 (Naval Observatory)	14	20	+18.5	107.2	+11.0		37	37
Nov. 18 (Naval Observatory)	11	47	+32.0	108.9	+10.5		31	31
Nov. 19 (Perkins Observatory	11	20	+43.5	107.7	+10.5		62	62
Nov. 20 (Naval Observatory)	10	8	−79.0	332.4	+9.0	247		
			+60.5	111.9	+10.0	46		293
Nov. 21 (Naval Observatory)	10	20	−70.0	328.2	+9.0		463	
			−23.0	15.2	+10.5		31	494
Nov. 22 (Naval Observatory)	13	14	−55.0	328.4	+9.5		463	
			−9.5	13.9	+10.5	15		
			+5.5	28.9	+11.0		37	515
Nov. 23 (Naval Observatory)	10	54	−42.5	329.0	+10.0		401	
			+17.0	28.5	+11.0		31	432
Nov. 24 (Naval Observatory)	10	11	−30.0	328.7	+10.0		401	401
1931								
Nov. 25 (Naval Observatory)	14	12	−53.5	289.8	−1.0	31		
			−14.5	328.8	+10.0		401	432
Nov. 26 (Naval Observatory)	10	45	−21.0	311.0	+12.0		31	
			−2.5	329.5	+9.5		432	463
Nov. 27 (Perkins Observatory)	11	51	−5.5	312.8	+13.5		80	
			0.0	318.3	+9.0	51		
			+10.0	328.3	+10.0		330	461
Nov. 28 (Mount Wilson)	13	0	+7.0	311.4	+12.0		31	
			+25.0	329.4	+10.0		340	371
Nov. 29 (Mount Wilson)	14	20	+19.0	309.6	+13.0		75	
			+38.0	328.6	+10.0		287	362
Nov. 30 (Yerkes Observatory)	10	21	+28.5	308.2	+13.5	14		
			+29.0	308.7	+14.0	3		
			+31.5	311.2	+14.5	6		
			+36.5	316.2	+12.0	3		
			+45.5	325.2	+10.0	190		
			+47.5	327.2	+10.5	7		
			+49.0	328.7	+10.0	19		
			+54.0	333.7	+10.0	334		576
Mean daily area for November								201

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, NOVEMBER, 1931

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished througb the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

November, 1931	Relative numbers	November, 1931	Relative numbers	November 1931	Relative numbers
1	8	11	0	21	29
2	14	12	0	22	39
3	Ec 17	13	0	23	33
4	18	14	0	24	
5	24	15		25	44
6		16	0	26	Mbc 42
7	a 13	17	8	27	a 34
8	12	18	14	28	31
9	16	19	10	29	
10	0	20	d 16	30	26

Mean: 26 days=17.2.

a=Passage of an average-sized group througb the central meridian.
b=Passage of a large group or spot through the central meridiau.
c=New formation of a center of activity: E, on tho eastern part of tho suu's disk; W, on the western part; M, in the contral zone.
d=Entrance of a large or average-sized center of activity on tbe east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in charge]

By L. T. SAMUELS

In Table 1 are shown the mean monthly free-air temperatures and relative humidities. While normals are not available at all of these stations, the means in such cases were compared with the normals of near-by aerological stations. The temperature departures were positive in all cases with the largest values occurring at Cleveland. Relative humidities were above normal at all levels at Dallas and Due West and at the lower levels at Cleveland, Chicago, and Omaha and below normal elsewhere.

At and below the 1,000-meter level the monthly resultant winds contained a greater southerly component than normal over a large portion of the southern and central part of the country. (Table 2.) Over New England the resultant velocities were mostly above normal. At 3,000 meters the monthly resultants were close to the normal values at all stations except in the extreme northwest and southeast. In the former region the monthly resultant direction was northerly as compared to a normal westerly and in the latter region this direction was easterly as compared to a normal northerly. In most cases the resultant velocities were less than normal.

In Table 3 are shown the mean and extreme heights reached during the month. Three airplane observations were missed during the month at Omaha and one at Chicago, due to unfavorable weather conditions.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during November, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (3 meters)	Omaha, Nebr.[1] (299 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)
Surface	7.4	7.4	12.9	11.7	−0.4	12.2	4.6	16.8	16.
500	7.3	7.7	14.1	12.9	0.0	14.4	5.3	17.3	13.
1,000	6.5	7.2	13.2	12.2	1.6	11.7	6.5	14.9	12.
1,500	4.2	5.1	11.9	9.6	1.0	------	5.5	------	----
2,000	2.8	3.4	9.8	7.8	−0.9	5.0	4.3	10.9	6.
2,500	0.8	1.6	7.3	6.1	−3.5	------	2.5	------	----
3,000	−1.7	−0.7	5.2	4.4	−5.9	1.7	−0.5	6.9	1.
4,000	−6.5	−5.0	−0.6	−1.2	−11.1	------	−6.9	------	----
5,000	−11.5	−9.8	−7.5	------	−17.1	------	−13.7	------	----
6,000	------	−17.2	−15.7	------	------	------	−21.1	------	----

RELATIVE HUMIDITY (PER CENT)

Altitude (meters) m. s. l.	Chicago	Cleveland	Dallas	Due West	Ellendale	Hampton Roads	Omaha	Pensacola	San Diego
Surface	83	78	84	76	78	81	82	86	5
500	75	74	75	69	76	62	75	77	5
1,000	69	70	68	65	63	60	62	72	4
1,500	61	67	65	64	56	------	55	------	----
2,000	51	55	64	62	52	55	46	59	3
2,500	45	49	60	52	54	------	40	------	----
3,000	44	46	19	45	55	23	41	48	3
4,000	36	36	44	41	62	------	39	------	----
5,000	33	30	41	------	80	------	36	------	----
6,000	------	20	79	------	------	------	35	------	----

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m (E. S. T.) during November, 193*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 10 E	0.3	S 43 E	1.1	S 29 W	2.5	N 76 W	4.5	S 48 W	3.1	S 24 W	3.0
500	------	---	S 29 E	8.7	S 39 W	7.4	------	---	S 69 W	7.4	S 57 W	8.4
1,000	------	---	S 23 E	10.3	S 70 W	7.1	------	---	S 80 W	10.5	S 72 W	10.1
1,500	------	---	S 13 E	8.2	S 89 W	9.9	------	---	S 82 W	10.5	S 78 W	10.9
2,000	S 43 W	1.8	S	5.8	N 87 W	10.5	N 80 W	6.2	S 80 W	10.6	S 86 W	11.6
2,500	S 64 W	3.9	S 2 E	4.7	N 89 W	9.8	N 68 W	8.9	------	---	N 89 W	12.3
3,000	S 72 W	5.5	S	2.1	S 83 W	11.3	N 80 W	6.2	------	---	------	---
4,000	S 64 W	9.4	S 26 E	1.3	------	---	W	7.7	------	---	------	---
5,000	S 76 W	9.6	S 47 W	0.7	------	---	S 83 W	10.4	------	---	------	---

Altitude (meters) m. s. l.	Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 29 E	2.2	N 33 E	0.9	N 53 W	1.8	S 61 W	2.6	N 6 W	1.7	N 49 E	3
500	S 2 W	6.7	N 16 E	0.2	N 64 W	2.1	------	---	N 60 E	5.5	N 66 E	11
1,000	S 34 W	6.9	S 31 W	1.2	N 79 W	4.6	S 66 W	5.0	N 76 E	4.2	S 78 E	10
1,500	S 58 W	7.0	S 73 W	1.7	N 73 W	6.1	S 83 W	6.6	N 87 E	3.1	N 80 E	9
2,000	S 72 W	6.4	N 80 W	3.2	N 71 W	8.6	N 82 W	9.0	N 3 E	2.4	N 70 E	8
2,500	S 65 W	6.6	N 74 W	4.0	N 73 W	10.3	N 81 W	10.4	N 18 W	2.8	N 76 E	7
3,000	S 61 W	7.2	N 77 W	4.6	N 72 W	11.9	N 72 W	9.7	N 42 W	6.0	N 73 E	7
4,000	S 79 W	9.7	N 69 W	7.4	------	---	N 82 W	13.8	N 70 W	10.4	N 24 E	5
5,000	------	---	N 59 W	9.7	------	---	------	---	------	---	------	--

Altitude (meters) m. s. l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (89 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	N 35 W	0.4	S 11 E	0.1	S 13 E	1.5	N 86 E	1.6	N 41 E	1.9	S 10 W	1.8
500	N 43 E	1.3	N 8 E	0.3	S 14 W	6.1	S 48 E	7.0	N 2 E	3.7	S 15 W	4.2
1,000	N 62 E	1.8	S 7 W	0.9	S 43 W	5.4	S 45 E	4.4	N 5 W	5.3	S 51 W	8.2
1,500	N 43 E	2.5	S 35 W	2.9	S 46 W	5.9	S 46 E	2.0	N 12 W	6.2	S 62 W	7.5
2,000	N 4 W	3.4	S 78 W	3.5	S 75 W	3.0	N 45 E	1.3	N 11 W	5.7	S 59 W	7.8
2,500	N 29 W	3.4	N 67 W	3.1	S 65 W	3.8	S 62 E	0.5	N 7 W	7.5	S 63 W	7.5
3,000	N 48 W	4.5	N 57 W	3.5	S 48 W	5.4	S 85 W	3.5	N 14 W	8.6	S 62 W	7.7
4,000	------	---	N 32 W	4.4	------	---	------	---	N 21 W	8.4	N 87 W	7.1
5,000	------	---	------	---	------	---	------	---	------	---	------	---

Altitude (meters) m. s. l.	Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°	
Surface	S 4 W	0.7	N 87 E	2.3	S 20 E	3.0	S 65 W	1.3	S 43 E	1.7	S 20 W	0
500	S 58 W	2.6	S 86 E	2.6	------	---	S 75 W	5.8	S 23 W	3.1	S 84 W	5
1,000	S 87 W	7.2	S 69 E	1.7	------	---	N 83 W	9.5	S 20 W	3.5	N 73 W	6
1,500	S 87 W	8.6	S 4 E	1.4	S 8 E	4.7	N 59 W	9.3	S 75 W	1.3	N 70 W	9
2,000	N 83 W	9.4	S 27 W	2.2	S 19 W	3.6	N 70 W	9.7	N 1 E	2.5	N 67 W	9
2,500	N 89 W	9.4	S 74 W	2.9	S 48 W	2.7	------	---	N 8 W	3.7	N 72 W	1(
3,000	N 79 W	8.8	S 66 W	3.0	S 76 W	2.7	------	---	N 9 W	4.5	N 76 W	12
4,000	N 82 W	8.4	S 46 W	3.0	N 68 W	3.2	------	---	------	---	------	--
5,000	------	---	------	---	N 59 W	3.4	------	---	------	---	------	--

TABLE 3.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during November, 1931*

	Dallas, Tex.[1]	Due West, S. C.[2]	Ellendale, N. Dak.[2]	Chicago, Ill.[1]	Cleveland, Ohio[1]	Omaha, Nebr.[1]
Mean altitudes, meters, m. s. l., reached	5,476	2,616	2,970	4,603	5,526	6, [illegible]
Maximum altitude, meters, m. s. l., reached	6,018	4,692	5,069	5,110	6,018	6, [illegible]
Number of flights made	30	30	27	29	30	
Number of days on which flights were made	30	30	26	29	30	

[1] Airplanes. [2] Kite.

WEATHER IN THE UNITED STATES

[Climatological Division, Oliver L. Fassig, in Charge]

THE WEATHER ELEMENTS

By M. C. Bennett

GENERAL SUMMARY

The weather during November was abnormally warm in most sections from New England westward to the Great Plains. In the more southern States the temperature averaged from 4° to 7° above the normal while in the Great Plains it was only slightly above. On the other hand, from the Rocky Mountain region to the Pacific coast subnormal temperature prevailed, although the departures were but a few degrees below the seasonal average.

The precipitation for the month was abnormally heavy throughout much of the upper Mississippi and lower Missouri Valleys, with an area including central and western Iowa, northwestern Missouri, eastern Kansas, and central Oklahoma reporting from four to five times the normal. Likewise portions of southern Arizona received nearly five times their normal. On the other hand, portions of the Southeast and Northwest received no appreciable precipitation during the month, and portions of the Eastern States from New England to Alabama received less than 25 per cent of the seasonal average; also southern and western Texas and portions of the northern Great Plains, the Pacific Northwest, and northern California received subnormal amounts. Snowfall was moderately heavy over the Rocky Mountain region, but only slight amounts were reported to the eastward.

TEMPERATURE

The first week was generally cool in the eastern and south-central portions, but warm elsewhere, being particularly warm compared with normal in the middle and northern Plains, Rocky Mountain, and Plateau States. From the beginning of the second week till the 24th, decided warmth for November prevailed in the eastern half of the country, and until about the 17th the Plains States and New Mexico usually had warm weather. In the central valleys and to northeastward over the upper Ohio Valley and most of the Lake region the warmth was beyond precedent at this time of year, the departure from normal being about 20°.

Much colder weather set in over most of the Rocky Mountain and Plateau States about the middle of the month, and the Plains States and nearly all of the Mississippi Valley gradually came under its influence as the final decade passed; but the South Atlantic and East Gulf States remained warmer than normal. The last ten days of November were remarkably cold in Montana, Idaho, Utah and large portions of adjoining States.

November averaged colder than normal near and to the westward of the Rocky Mountains, notably in the northern and middle Plateau region and the interior counties of the Pacific States, where it was 4° to 6° colder than normal.

At Eureka, Calif., and Boise, Idaho, this was the coldest or almost the coldest November of record. Some stations in southern California and Montana reported it the first month with mean temperature below normal since the fall of 1930.

Between the western Plains and the Mississippi River, likewise in the Florida Peninsula, this month was moderately to considerably warmer than normal. East of the Mississippi River, save in the Florida Peninsula, this month was almost invariably the warmest November of record. From Tennessee and Missouri northeastward over the Lake region the month averaged 8° to 11° above normal.

The highest marks of several Southwestern States were above 95°. In most States they were in the 80's, but in the majority of northern border States between 75° and 80°. To the westward of the Mississippi River they almost invariably occurred not later than the 8th, but to the eastward usually just before the middle of the month or about the 22d.

The lowest temperatures of the far Western States were considerably below zero, one elevated station in Colorado reporting −41°. In the northern Plains and Minnesota they were several degrees below zero, but in and to the eastward of the middle and lower Mississippi Valley they were mainly between 14° and freezing. In the southeastern quarter of the country the 7th was, as a rule, the coldest day; otherwise the lowest readings occurred almost always on some day of the last decade of the month.

PRECIPITATION

The first decade was a period of decidedly little precipitation, although the North Pacific States were favored. The middle decade and the first half of the last decade brought important precipitation to considerable portions of the Pacific and Plateau regions, also to most of the Plains, the Mississippi Valley, and the upper Lake region, the amounts being notably large in Iowa, Wisconsin and the northern parts of Missouri and Illinois, also considerable portions of Kansas and Oklahoma.

The last few days of November saw somewhat better distribution of precipitation. Moderate to locally heavy falls occurred almost throughout the Ohio and lower Mississippi Valleys and eastern Texas. There continued, however, to be very little rainfall, or locally none at all, in most of Georgia and large parts of the Carolinas, northern Florida, and southeastern Alabama.

The month brought more ample precipitation than the earlier fall months, except near the Atlantic and east Gulf coasts and in a few small areas elsewhere. There usually was moderately less than normal, however, near the Appalachian crest and for a few hundred miles or more to the northwestward, and in the lower Lake region, southern Mississippi and adjacent areas, central and southwestern Texas, the Black Hills region, and the western half of North Dakota. In the Pacific Northwest amounts often were somewhat less than normal.

There was generally a moderate excess above normal in Colorado, New Mexico, Arizona, southern California, the northern Plateau region, and from the eastern parts of the Dakotas to the upper Lake region. At Phoenix, Ariz., the rainfall was 3.18 inches, nearly five times the normal, and with one exception the greatest November amount ever known there.

Rainfall was decidedly heavy for late fall from central Oklahoma northeastward to Iowa, most stations measuring from four to six times their November normal quantities, and exceeding, often by 1 or 2 inches, the previous greatest November precipitation of the locality. As far southwestward as the northwestern part of Texas, and as far eastward as Arkansas, the lower Ohio Valley,

western Indiana, and the vicinity of Lake Michigan there was considerably greater precipitation than normal.

As an indication of the plentiful water supply in recent months over the north-central part of the country, the river stage at St. Louis, Mo., may be noted. On November 30 this reached 22 feet, which was 8 feet below flood stage, but was higher than any previous stage since the latter part of June, 1929.

SNOWFALL

There was practically no snowfall anywhere during the first decade. The middle decade brought a little snow in the northernmost districts from central North Dakota to the western end of Lake Superior and considerable over most of the northern Plateau region, 12 inches falling at Salt Lake City, Utah. During the final decade snowfall occurred in most districts where it is expected by the end of November, though scarcely any fell to the southward of the northern boundaries of Arkansas, Kentucky, and the Virginias. From the lower Missouri Valley to New Jersey a narrow strip received from 2 to 6 or 7 inches about the 26–27th. However, several districts farther northward, particularly large portions of Wisconsin and lower Michigan, received no measurable snow before November ended and most of the Lake region and northern New England had far less than normal.

Most of the Plateau region received snowfall during the closing decade, and some districts a short distance to the eastward of the Divide had unseasonably heavy falls, Denver, Colo., recording almost 15 inches and El Paso, Tex., over 2 inches.

The month's total snowfall was usually less than normal in the eastern half of the country, except moderately above normal from Indiana to New Jersey. In the Plains States and to the westward it was mainly greater than normal. In Idaho the average fall was larger than in any previous November of record, and the records were approached in Utah, Arizona, and New Mexico.

SUNSHINE AND RELATIVE HUMIDITY

The sunshine during November was slightly above the normal locally in the Southeast, the northern Great Plains, the Lower Lakes, and north Pacific areas. Elsewhere it was below the seasonal average, the deficiency being rather pronounced in portions of the upper and central Mississippi and lower Missouri valleys and the central Great Plains.

The relative humidity during the month was generally above the normal from the Plateau and Rocky Mountain regions eastward, except in portions of the southeast and northwest, and locally in the Lake region, where the average was as a rule slightly below. Throughout the Pacific States the humidity was generally below the normal although the departures were small, for the most part.

SEVERE LOCAL STORMS, NOVEMBER, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Mapleplain, Minn. (vicinity of).	16	9:35 p. m.			$12,000	Tornado	Some farm buildings totally demolished or badly damaged; telephone poles leveled for half a mile; path 5 miles long.	Official U. S. Weather Bureau.
Lindale (near), Tex.	17	5 a. m.	200		3,500	do	Buildings damaged at Thedford Switch.	Do.
Longview, Tex.	17	6 a. m.				Wind	8 oil derricks blown down in Spring Hill community.	Do.
Ludington, Mich.	20	11:30-2:40 p. m.				do	Poles and overhead wires damaged; 1 person injured.	Do.
Charles City, Iowa, and vicinity.	20	2:14 p. m.			15,000	Thunderstorm and wind.	Airplane wrecked and another damaged; garage unroofed; buildings on 7 farms damaged.	Do.
Trempeleau County, Wis.	20	4 p. m.			15,500	Squall winds	Schoolhouse and several small buildings wrecked, others damaged; livestock killed.	Do.
Winnsboro (near), La.	20					2 small tornadoes.	Some small buildings demolished, several others damaged; poultry and pigs killed.	Do.
Santa Fe, N. Mex., and vicinity.	21-22				1,000	Wind	Signs, roofs, awnings, and outbuildings damaged.	Do.
Catron, Valencia, McKinley, San Juan, Rio Arriba and Sandoval Counties, N. Mex.	21-23			9	50,000	Snow, wind, and cold.	Many Indians badly frozen; thousands of sheep lost.	Do.
Amarillo, Tex.	22					Rime	Much damage to telephone and light wires.	Do.
Barton, Rush, and Ness Counties, Kans.	22-23				10,000	Sleet and glaze	157 poles broken down; 1,000 breaks in wires; power and telephone service greatly hampered.	Do.
Butler, Polk, York, and Fillmore Counties, Nebr.	22-23				80,000	Ice	Considerable injuries to trees and overhead wires.	Do.
Monroe, Audubon, Mahaska, Wapello, Fremont, Mills, and Pottawattamie Counties, Iowa.	22-23					Heavy rains and floods.	Considerable damage to crops, especially unhusked corn, by inundating of farm lands; fences and wooden bridges damaged.	Do.

RIVERS AND FLOODS

By Montrose W. Hayes

[In charge River and Flood Division]

Rains in the latter half of November caused moderate ›ods in the Illinois, the Des Moines, the Missouri River low Kansas City, the Osage, the Neosho, and Verdigris Kansas, and the Long Tom, a tributary of the Willam- te, in Oregon. There was also an overflow in the Dela- are, a small stream tributary to the Kansas River.

In the Grand River of Missouri there was a moderately gh flood, which caused a severe loss to unhoused crops. The following is a statement of flood losses:

angible property totally or partially destroyed (buildings, fences, highways, bridges, railroads, etc.):	
Grand River	$56, 000
Osage River	7, 500
Verdigris River	500
Neosho River	500
Total	64, 500
atured crops:	
Illinois River	10, 000
Grand River (in Missouri)	636, 000
Osage River	5, 600
Missouri River below Kansas City	14, 000
Neosho River	1, 000
Total	666, 600
ospective crops: Neosho River	500
vestock and other movable property:	
Osage River	1, 000
Neosho River	300
Total	1, 300
ispension of business, including wages of employees:	
Osage River	2, 000
Neosho River	500
Total	2, 500

A complete report on the extent of the Des Moines iver flood has not been received. It will appear in the ecember issue of the Review.

The money value of property saved by warnings was estimated at $25,000 in the Grand Valley, $7,000 in the Osage Valley, and $5,000 in the lower Missouri Valley.

Table of flood stages in November, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
	Feet			Feet	
Raccoon: Van Meter, Iowa	13	24	24	14. 2	24
Des Moines: Ottumwa, Iowa	10	24	29	12. 2	26–27
Illinois:					
Morris, Ill	13	23	23	13. 3	23
Peru, Ill	14	22	(1)	17. 5	24
Henry, Ill	10	26	30	10. 1	27–28
Havana, Ill	14	29	(1)	14. 0	29–30
Missouri Basin					
Thompson Fork: Trenton, Mo	20	24	24	20. 4	24
Grand:					
Gallatin, Mo	20	14 23	19 27	29. 3 32. 6	16 26
Chillicothe, Mo	18	15 23	21 28	28. 3 29. 8	17 25
Brunswick, Mo	12	18	(1)	18. 9	27
Osage:					
Quenemo, Kans	30	24	25	34. 6	24
Ottawa, Kans	24	24	26	27. 2	25
La Cygne, Kans	23	25	28	24. 1	28
Missouri:					
Boonville, Mo	21	28	29	21. 4	28
St. Charles, Mo	25	29	30	26. 1	30
Arkansas Basin					
Verdigris: Independence, Kans	30	24	26	36. 2	25
Neosho:					
LeRoy, Kans	24	24	24	25. 4	24
Iola, Kans	15	24	26	16. 4	24
Chanute, Kans	20	24	27	23. 0	26
Parsons, Kans	22	26	28	23. 0	28
Oswego, Kans	17	25	29	19. 7	28
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Long Tom: Monroe, Oreg	8	22	22	11. 1	22

[1] Continued into December.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By the Marine Division, W. F McDonald in charge]

NORTH ATLANTIC OCEAN

By W. F. McDonald

The pressure situation.—The weather of November, 931, on the North Atlantic Ocean was characterized y an unusually deep and persistent Icelandic low, ith barometric averages near or somewhat above the ovember normal over most of the region south of lati- ide 40°. Highest pressures were central over the merican coast northward to Halifax, where the barom- ter averaged 0.10 to 0.15 inch above normal. From eland to Iceland, the average pressure was nearly a alf inch below normal, and on more than half the days the month the minimum barometric readings on the ortheastern Atlantic were below 29 inches. There as a slight deficiency in the mean pressure in the Carib- ean area.

Table 1 gives details of average pressures, departures om normal, and maxima and minima for a number of oastal and island stations representative of the North tlantic region.

Table 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, November, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Julianehaab, Greenland [1]	29. 49		30. 14	19th	28. 90	27th.
Reykjavik, Iceland [1]	29. 12	−0. 50	29. 71	30th	28. 58	14th.
Lerwick, Shetland Isles [1]	29. 60	−0. 10	30. 39	16th	28. 49	10th.
Valentia, Ireland [1]	29. 59	−0. 45	30. 34	30th	28. 46	10th.
Lisbon, Portugal [1]	30. 08	+0. 04	30. 26	28th	29. 78	12th.
Madeira [1]	30. 08	+0. 07	30. 24	27th	29. 88	14th.
Horta, Azores [1]	30. 14	+0. 01	30. 44	19th	29. 94	13th.
Belle Isle, Newfoundland [1]	29. 83	−0. 05	30. 64	20th	28. 82	14th.
Halifax, Nova Scotia [1]	30. 10	+0. 15	30. 56	20th	29. 50	4th.
Nantucket [2]	30. 17	+0. 12	30. 58	27th	29. 66	30th.
Hatteras [2]	30. 23	+0. 12	30. 52	26th	29. 96	30th.
Bermuda [1]	30. 15	+0. 07	30. 36	20th	29. 90	10th.
Turks Island [1]	29. 97	−0. 02	30. 08	27th	29. 82	8th.
Key West [2]	30. 04	+0. 02	30. 17	11th	29. 90	30th.
New Orleans [2]	30. 14	+0. 04	30. 38	2d	29. 86	17th.
Cape Gracias, Nic.[1]	29. 84	−0. 06	29. 94	27th	29. 76	14th.

[1] All data based on a. m. observations only, with departure computed from best available normals related to time of observation.
[2] Corrected 24-hour means, based on more than one observation daily.

Great pressure contrasts and active disturbances marked the first half of the month. The period from the 7th to the 10th was stormiest, and on the 9th the LOW in the northeastern Atlantic attained its maximum development, with a central isobar of 28.2 inches clearly identified in the data reported. At the same time a well defined HIGH was present on the American coast, so that a pressure gradient of more than two inches existed between the Grand Banks and the northeastern Atlantic. The situations of the four days November 7 to 10 inclusive, have been chosen for reproduction as Charts VIII to XI, appended to this issue of the REVIEW.

The latter part of the month was, in general, more equable, but was not without several short periods of rather active disturbance. The storm developments of this period arose in several instances well southward in the Atlantic, one being a small but clearly identifiable depression appearing on the 21st southwest of the Azores, and another a similar disturbance, reaching its full development about the 23d, southwest of Bermuda. Both of these LOWS moved northward to unite with more extensive depressions over the northern Atlantic.

Gales and tropical disturbances.—As might have been expected from the general pressure situation outlined above, the stormiest part of the Atlantic during November was north of latitude 45° and east of longitude 30°, in the region which was most persistently under the influence of deep barometric depressions. However, gales occurred on a few days in other areas westward to the Grand Banks, and thence southwestward toward the Bahamas.

The stormiest days on the main trans-Atlantic routes were the 3d and the 7th to the 10th and the 13th to the 15th, inclusive. Winds of whole gale force were reported at places along the routes on each of those days, and hurricane force was encountered by the German ship *New York*, westbound near longitude 25°, on the night of the 8th, and also by the Belgian steamer *Emanuel Nobel*, eastbound on the 13th, in the same area. A number of liners reported delays in crossing due to the heavy weather of this period. A British schooner of 190 tons had to be abandoned by her crew of seven on November 17th in mid-Atlantic due to the long continued storminess of the preceding weeks.

At the beginning of the month a mild disturbance over the western Carribbean Sea produced a distinctive cyclonic circulation which was reported of gale force on the 2d by the Panamanian ship *San Blas*, but the disturbance failed to develop a definite center of low pressure. About a week later, another gale was experienced in the western Caribbean, and news dispatches reported extraordinary rains and storm damage in Honduras, but these appear to have been due to an intensification of the trade winds rather than to a true tropical disturbance.

Fog.—November was almost entirely free from fog over most of the Atlantic, Gulf, and Caribbean waters. Practically all fog reports at hand were received from the region adjacent to the American east coast north of Hatteras, where fogginess was experienced on 5 to 10 days, mainly during the latter half of the month.

OCEAN GALES AND STORMS, NOVEMBER, 1931

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
San Blas, Pan. S. S.	Castilla	Boston	16 40 N	85 30 W	Nov. 1	6 a., 2	Nov. 2	29.78	WSW	WNW, —	NW	WSW, 9	WSW-WNW.
Dresden, Ger. S. S.	Galway	New York	51 11 N	27 01 W	Nov. 3	Noon. 3	Nov. 3	29.04	WNW	—, 11	WNW	NW, 11	
Saccarappa, Am. S. S.	Sluiskill	Charleston	47 00 N	13 12 W	Nov. 2	7 a., 3	Nov. 4	29.32	SSW	SW, 9	W	SW, 10	SSW-WNW.
Seminole, Br. S. S.	Ellesmere Port.	Baton Rouge	51 43 N	6 38 W	do	Mdt., 3	do	29.07	S	SW, 10	W	SW, 10	SW-W.
Santa Marta, Am. S. S.	Honduras	New York	17 00 N	86 57 W	Nov. 3	4 a., 4	do	29.85	WNW	NW, 8	N	NW, 8	WNW-N.
Manistee, Br. S. S.	Liverpool	Jamaica	47 03 N	16 59 W	Nov. 5	8 p., 6	Nov. 9	28.97	S	WNW, 10	W	—, 10	WNW-NW.
Tachira, Am. S. S.	New York	Venezuela	25 41 N	68 48 W	Nov. 7	10 a., 7	Nov. 10	29.78	NE	NE, 8	ENE	NE, 9	NE-ENE.
Oranian, Br. S. S.	Halifax	Bristol Channel.	47 21 N	49 47 W	do	8 a., 7	Nov. 7	29.21	W	W, 3	NNW	NW, 10	
Emanuel Nobel, Belg. S. S.	Philadelphia	Manchester	43 55 N	45 22 W	Nov. 8	Mdt., 8	Nov. 9	29.57	NW	NW, 10	NW	—, 10	NW-NNW.
Braheholm, Swed. S. S.	Newcastle-on-Tyne.	Portland, Me.	55 20 N	29 54 W	do	10 p., 8	Nov. 10	28.22	SE	NE, 4	NW	NW, 11	NE-N.
New York, Ger. S. S.	Cherbourg	New York	49 00 N	24 42 W	do	2 p., 8	do	28.74	S	—, 10	NW	—, 12	S-W-NW.
Kattegat, Ger. M. S.	Batum	Hamburg	46 40 N	6 31 W	Nov. 5	—, 8	Nov. 8	28.92	WSW	W, 8	N	WSW, 10	W-NW.
Southern Prince, Br. M. S.	New York	Rio de Janeiro.	30 44 N	60 57 W	Nov. 8	4 a., 9	Nov. 9	29.77	ENE	NE, 9	SSE	NE, 9	NE-SE.
Carlier, Belg. S. S.	Antwerp	New York	49 20 N	21 10 W	do	2 p., 9	Nov. 10	29.09	WSW	W, 11	WNW	NW, 11	WSW-WNW.
Clairton, Am. S. S.	New York	Manchester	50 50 N	17 00 W	Nov. 7	4 a., 10	do	28.66	SSW	W, 7	W	W, 10	SSW-W.
Vincent, Am. S. S.	Havre	New York	48 25 N	11 02 W	Nov. 9	4 a., 10	Nov. 11	28.85	WSW	WSW, 10	WSW	WSW, 10	Steady.
Wytheville, Am. S. S.	Rotterdam	Boston	50 55 N	21 50 W	Nov. 12	5 a., 13	Nov. 14	28.78	S	S, —	W	W, 10	S-SW-W.
Emanuel Nobel, Belg. S. S.	Philadelphia	Manchester	50 31 N	21 33 W	Nov. 13	—, 13		28.88	S	S, 10	W	SSW, 12	
Europa, Ger. S. S.	Cherbourg	New York	49 17 N	23 14 W	Nov. 12	2 a., 13	Nov. 15	28.87	S	—, 10	ENE	WNW, 11	
Tusearora, Br. S. S.	Glasgow	Galveston	50 27 N	18 08 W	Nov. 13	7 a., 13	Nov. 14	29.32	SSW	SSW, 11	S	—, 11	S-SW-W.
Schenectady, Am. S. S.	Copenhagen	Portland, Me.	58 45 N	8 00 W	do	4 p., 13	Nov. 21	29.19	SSE	S, 8	NW	NW, 11	S-SW.
Forthbank, Br. S. S.	New Orleans	Canal Zone	15 38 N	81 15 W	do	4 p., 14	Nov. 14	29.84	ENE	E, 7	ESE	E, 9	E-ESE.
West Chatala, Br. S. S.	Galveston	Havre	44 16 N	44 15 W	Nov. 14	11 p., 14	do	29.44	NNW	SSW, 10	NW	SSW, 10	SSW-NW.
Aquitania, Br. S. S.	New York	Southampton	41 32 N	56 21 W	Nov. 15	4 p., 15	Nov. 17	30.06	NW	NW, 8	NW	NW, 9	NW-NNW.
West Quechee, Am. S. S.	Hamburg	Galveston	40 20 N	22 44 W	Nov. 22	Noon, 22	Nov. 22	29.39	SSE	NE, 9	NNW	—, 9	SSE-E-NNW.
Ponce, Am. S. S.	New York	Porto Rico	31 15 N	70 18 W	Nov. 23	8 p., 23	Nov. 24	29.81	E	E, —	ESE	ESE, 10	E-ESE.
Prusa, Am. S. S.	Galveston	Barcelona	30 42 N	68 42 W	do	3 p., 23	do	29.90	ENE	ENE, —	E	—, 10	
Gulf Hawk, Am. S. S.	Las Piedras	Philadelphia	26 19 N	75 16 W	Nov. 24	Noon, 24	do	29.52	SW	SW, 7	N	W, 10	SW-W.
City of Hamburg, Am. S. S.	Hamburg	Baltimore	49 04 N	27 03 W	Nov. 22	Noon, 25	Nov. 27	29.24	S	W, 8	W	—, 10	W-NW.
Bremen, Ger. S. S.	Cherbourg	New York	47 06 N	37 18 W	Nov. 30	Mdt., 30	Dec. 1	28.98	SSE.	—, 12	NW	—, 12	
Aden Maru, Jap. S. S.	Fowey, England.	Portland, Me.	46 53 N	38 55 W	Nov. 29	8 p., 3	do	29.15	S	SW, 11	WNW	SW, 12	S-SW-WNW.
Bellflower, Am. S. S.	Avonmouth	Baltimore	51 35 N	23 43 W	Nov. 30	3 a., 30	Nov. 30	29.68	SSE	SSE, 8	NW	SSE, 10	SSE-NNW.

OCEAN GALES AND STORMS, NOVEMBER, 1931—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN			° ′	° ′				Inches					
kushika Maru, Jap. S. S.	Miike	Port Townsend.	49 07 N	154 10 E	Oct. 30	Mdt., 3	Nov. 4	29.33	S	S, 9	S	S, 9	Steady.
p. of Asia, Can. S. S.	Vancouver	Yokohama	45 35 N	158 11 E	Nov. 1	2 a., 2	Nov. 2	29.50	SW	W, 8	W	WNW, 10	SW-W-WNW.
ief Capilano, Br. S. S.	do	do	48 15 N	166 45 E	Nov. 2	4 p., 2	Nov. 3	29.22	SW	WSW, 10	NW	W, 11	WSW-W.
nois, Am. S. S.	Portland	do	47 03 N	164 10 E	do	1 p., 2	Nov. 4	29.32	S	W, 11	N	W, 11	WSW-W.
lden Wall, Am. S. S.	Hong Kong	San Francisco	46 09 N	172 30 W	do	1 p., 2	do	29.60	W	WSW, —	WNW	WSW, 9	WSW-W.
ndareus, Br. S. S.	Yokohama	Victoria	49 00 N	177 40 W	do	4 p., 4	do	29.06	WSW	WNW, 9	WNW	W, 10	WNW-NW.
lville Dollar, Am. S.	Cebu, P. I.	Los Angeles	39 27 N	140 01 W	do	2 a., 3	do	29.41	NE	N, 10	W	NNE, 11	2 pts.
anta, Br. S. S.	Yokohama	San Pedro	44 43 N	178 18 W	do	8 a., 3	Nov. 5	29.37	WNW	W, 10	NW	W, 10	W-WNW.
o Maru, Jap. M. S.	do	San Francisco	47 20 N	167 38 W	do	3 p., 3	do	29.11	W	WSW, 9	W	WSW, 9	WSW-SW.
ska, Am. S. S.	Seattle	Seward	Resurrection Bay, Alaska		Nov. 3	3 p., 4	Nov. 4	29.62	S	S. 6		S, 10	Variable.
lingham, Am. S. S.	Dairen	San Francisco	47 45 N	177 45 W	do	8 a., 3	Nov. 5	29.04	W	W, 8	NW	W, 9	W-WNW-W.
ioan, Am. S. S.	New York	Los Angeles	15 20 N	93 25 W	Nov. 4	4 p., 4	Nov. 4	29.84	NW	NW, 5	NW	N, 9	
s. Jefferson, Am. S. S.	Victoria	Yokohama	52 31 N	158 48 W	Nov. 3	4 p., 4	Nov. 7	28.70	SSE	WSW, 5	NW	NW, 8	WSW-W.
pec, Am. S. S.	Portland	San Pedro	45 38 N	124 17 W	Nov. 6	—	Nov. 6	29.94	S	S, 7	SSW	S, 8	Steady.
len Whittier, Am. S.	Balboa	San Francisco	15 00 N	94 10 W	Nov. 8	5 p., 8	Nov. 9	29.87	NNW	NNW, 6	NNW	NNW, 10	Do.
art Dollar, Am. S. S.	Philippines	Los Angeles	15 15 N	128 00 E	Nov. 9	5 a., 9	do	29.68	NNE	E, 11	S	E, 11	ENE-E.
yo Maru, Jap. S. S.	Muroran	William Head	45 06 N	161 43 E	Nov. 10	11 p., 12	Nov. 13	28.55	S	NNW, 10	SW	WNW, 11	
s. Cleveland, Am. S.	Yokohama	Seattle	48 09 N	173 23 E	do	6 p., 12	Nov. 14	29.15	SE	SE, 9	S	SSE, 9	SE-S-WSW.
maha, Br. S. S.	Hong Kong	San Pedro	22 00 N	116 14 E	Nov. 11	6 a., 11	Nov. 11	29.52	ENE	NNE, 10	SE	NE, 11	NNE-NE.
lmay, Br. S. S.	Portland	Hankow	34 51 N	154 47 E	do	2 p., 11	Nov. 12	29.73	SSW	NW, 9	NW	NW, 9	SW-NW.
a, Am. S. S.	Japan	San Francisco	41 48 N	179 55 W	do	Noon, 12	do	29.63	S	SE, 7	SE	S, 9	S-SE.
igs, Am. S. S.	Manila	do	38 13 N	135 11 W	Nov. 14	6 a., 14	Nov. 14	29.93	NW	NW, 8	NNW	NW, 8	Steady.
lden River, Am. S. S.	Hong Kong	do	39 13 N	153 06 E	Nov. 17	1 p., 17	Nov. 17	29.59	W	NE, 9	NNE	NE, 9	W-NE.
agisan Maru, Jap. M.	Yokohama	do	45 57 N	172 23 W	Nov. 18	6 a., 19	Nov. 20	28.37	NE	W, —	SW	WSW, 9	ENE-W-WSW.
pec, Am. S. S.	San Pedro	Seattle	40 40 N	124 38 W	Nov. 22	2 p., 22	Nov. 23	29.99	NNW	N, 7	N	N, 8	Steady.
chigan, Am. S. S.	Tabaco, P. I.	San Francisco	26 00 N	137 20 E	do	8 p., 23	Nov. 24	29.31	ESE	S, 10	NW	S, 10	S-SW.
art Dollar, Am. S. S.	Philippines	Los Angeles	38 30 N	178 30 W	Nov. 23	4 p., 23	do	28.88	SE	SE, 4	NW	NNW, 12	
fiance, Am. M. S.	Shanghai	San Pedro	31 26 N	133 00 E	do	Mdt., 23	do	29.59	NE	ENE, 11	N	ENE, 11	NE-ENE.
Luis Maru, Jap. M.	Kudamatsu	Los Angeles	39 50 N	164 12 W	do	6 p., 23	do	29.11	SSE	SSE, 9	W	SSE, 9	SSE-S.
lden River, Am. S. S.	Hong Kong	San Francisco	46 35 N	170 19 W	do	2 p., 25	Nov. 26	29.13	N	S, 11	SW	SSE, 12	SSE-S.
p. of Russia, Can. S.	Vancouver	Yokohama	52 30 N	157 00 W	Nov. 24	7 p., 24	Nov. 25	29.71	SSE	SE, 9	SW	SE, 9	SE-S.
Do	do	do	52 00 N	168 00 W	Nov. 25	8 a., 25	Nov. 27	28.76	SW	S, 11	SW	S, 11	
yo Maru, Jap. S. S.	Muroran	Juan de Fuca	49 03 N	170 35 W	do	6 p., 25	Nov. 26	28.62	SE	S, 10	SW	SSW, 11	6 pts.
gon, Am. S. S.	Otaru	San Francisco	50 25 N	171 30 W	do	8 a., 25	do	28.44	SSE	SE, 11	W	S, 12	SE-S.
kubasan Maru, Jap. M. S.	Yokohama	do	45 10 N	175 33 W	do	5 a., 25	Nov. 27	28.63	SSW	SSW, 10	W	SSW, 10	1 pt.
art Dollar, Am. S. S.	Philippines	Los Angeles	38 18 N	152 00 W	Nov. 29	9 p., 29	Nov. 30	30.05	N	N, 8	NNE	N, 10	N-NNE.
fiance, Am. M. S.	Shanghai	San Pedro	41 24 N	163 30 E	do	3 a., 30	do	29.09	ESE	—, 8	NNW	NW, 11	SSW-W.
den Sun, Am. S. S.	Dairen	San Francisco	38 24 N	177 18 W	Nov. 30	Mdt., 30	do	29.77	S	NW, 8	NW	NW, 8	W-NW.
OUTH ATLANTIC OCEAN													
ria De Larrinaga, r. S. S.	England	Nacochca, Argentina.	Nacochea		Nov. 4	1 a., 4	Nov. 4	29.51	SW	SW, —	NNW	SW, 10	SW-W.
sier, Belg. S. S.	Buenos Aires	Santos	25 54 S	48 38 W	Nov. 7	4 a., 8	Nov. 8	29.43	NE	NNE, 9	NW	NNE, 9	NNE-NW.
silien, Dan. S. S.	Hull	Buenos Aircs.	31 20 S	48 40 W	Nov. 15	4 a., 16	Nov. 17	29.24	NE	WSW, 10	SW	WSW, 10	NW-W-S.

NORTH PACIFIC OCEAN

By Willis E. Hurd

Atmospheric pressure, November, 1931.—The average nter of the Aleutian Low in November was far to the stward of its October position, and lay over Bering a (St. Paul 29.50 inches, and Dutch Harbor 29.55 ches). At both these stations the pressure averages re below the normal for the month. Winter conditions pressure, with some extremely great and rapid fluctuans in the barometer from day to day, were common to e whole Aleutian region. Instances of this great presre variability are shown in the p. m. barometer readings Dutch Harbor from the 23d to the 27th, which are follows: 23d, 29.90 inches; 24th, 28.60; 25th, 29.68; th, 28.86; 27th, 29.80. Pressures above normal were und along the American coast from Kodiak eastward d southward to Tatoosh Island.

Fairly stable high pressure, with the average crest of e anticyclone over the eastern part of the ocean, evailed in middle latitudes, while a continuing belt of oderately high pressure extended westward along lower iddle latitudes to near the Asiatic coast. Here it panded to include Japanese waters and the eastern as of China. As usual to the season, in the Japanese gion the anticyclone was considerably broken by the trusion of frequent Lows.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

Table 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, November, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1 2]	30.00	+0.01	30.92	13th	29.20	28th.
Dutch Harbor [1]	29.55	−0.04	30.50	12th	28.60	3d.
St. Paul [1 2]	29.50	−0.09	30.40	12th	28.40	3d.
Kodiak [1]	29.68	+0.12	30.36	24th	29.02	5th.
Midway Island [1]	30.05	−0.03	30.24	29th	29.70	17th.
Honolulu [3]	29.99	−0.03	30.12	4th	29.85	26th.
Juneau [3]	29.95	+0.19	30.59	25th	29.20	1st.
Tatoosh Island [3 4]	30.02	+0.05	30.44	21st	29.28	16th.
San Francisco [3 4]	30.05	−0.04	30.38	19th	29.67	14th.
San Diego [3 4]	30.00	−0.02	30.20	19th	29.60	21st.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

Cyclones and storminess.—November, 1931, may be called a stormy month on the North Pacific. Moderate to intense progressive cyclones, as well as oscillating storms of the Aleutian Low type, swept upper and middle

latitudes. Typhoons and strong monsoons were felt in the Far East. Locally intensified trades, rising in force to that of a fresh gale, were reported on the 9th to 11th east of the Hawaiian Islands, and on several days Tehuantepecers roughened the weather off the Mexican south coast. But stormiest of all the regions was that lying approximately between latitudes 35° and 53° N., and longitudes 165° W. and 160° E. This region was traversed by most of the principal cyclones of the month.

The earliest northern cyclone of November, coming out of Siberia on the 1st, passed eastward over the Aleutians and entered the American mainland on the 6th. It was attended by fresh to whole westerly gales over an extensive area, involving the main trans-Pacific steamship routes south of the Aleutians, with the highest wind, force 11, on the 2d.

During the 9th to 12th another Siberian cyclone, after crossing the lower Kurils, sped northeastward and entered the Aleutian area. Its effects were experienced by shipping most severely on the 12th, during which day gales of varying forces up to 11 were reported along the upper route between 160° and 175° E.

About the 22d or 23d a storm development, secondary to a disturbance then over the Aleutians, appeared to the northeastward of Midway Island. At first it had a northwesterly trend about the HIGH then overlying the eastern part of the ocean, but by the 24th it was moving nearly north toward the Bering Sea, which it entered on the 26th. During most of its course it was a deep and violent cyclone. The heavy gales associated with it began on the 23d, when the American steamship *Stuart Dollar* encountered a northwesterly hurricane in 38° 30′ N., 178° 30′ W., barometer down to 28.88 inches. On the 25th several vessels experienced wind forces of 11 to 12, among them the American steamship *Oregon*, which encountered a southeast hurricane, with barometer down to 28.44 inches, in 50° 25′ N., 171° 30′ W. The cyclone continued northward with diminishing energy and by the 28th lay over northern Alaska and the adjacent Arctic Ocean.

During the 29th, in about 42° N., 163° E., the American motor ship *Defiance* encountered a northwest gale of force 11 in connection with a moderately deep cyclone, the earlier and subsequent movements of which are as yet little known.

Other gales of forces 8 to 10, not associated with the cyclones already mentioned, occurred at various times over the northern Pacific. They were for the most part connected with the fluctuating activities of the semipermanent Aleutian LOW. On the American coast fresh gales occurred on a few days, due to the proximity of depressions over the western extremity of the continent. The most important of these winds are mentioned in the tabular report of gales and storms.

One further extratropical cyclone needs to be mentioned. It gathered on the 1st of the month near 32° N., 147° W., in the midst of the North Pacific anticyclone. It had a slow northeast progression, but by the 3d, then central near 37° N., 137° W., it had penetrated the high-pressure area and joined the lower extension of the Aleutian cyclone to the northward. Thereafter it quickly lost identity and force, and only a very shallow depression remained of it off the California coast on the 4th. The cyclone attained local violence on the 3d, as may be gathered by the report of the American steamer *Melville Dollar*, which experienced a northerly gale of force 11, barometer down to 29.41 inches, while crossing the LOW near 39° N., 140° W.

Typhoons.—Three November typhoons appear to hav formed in the Far East. The first formed about midwa between Guam and the Philippines on the 3d or 4th It crossed central Luzon on the 7th and went westwar into the China Sea. We have no present informatio as to its intensity.

The second typhoon probably formed on the 6th o 7th in much the same locality as had its predecessor. I went northwestward over Luzon and seems to have en tered the China coast not far from Hong Kong on th 11th. Reports from two vessels indicate considerabl intensity both east and west of the Philippines. On th 9th the American steamer *Stuart Dollar* experienced a east gale of force 11, lowest barometer 29.68, in 15° N 128° E., and on the 11th the British tanker *Tamah* encountered this storm as a northeasterly gale of simila force, lowest barometer 29.52, some 130 miles east o Hong Kong.

The third typhoon originated a little west of Guam o the 17th. After a westward movement for two or thre days, it turned north, then went northeastward betwee the Ogasawara Islands and Japan, and disappeared a sea on the 24th near 40° N., 155° E. The America motorship *Defiance* experienced this cyclone as a gale force 11 on the 23d, in 31° 26′ N., 133° 00′ E.

Northers.—Northers were reported in the Gulf Tehuantepec from the 1st to the 8th, all of force 7, excep on the 4th, when the gale rose to force 9, and on the 8t when a force of 10 was encountered.

Winds at Honolulu.—The prevailing wind direction Honolulu was from the east, with a maximum velocit of 24 miles from the east on the 8th.

Fog.—Only three or four days with fog were reporte for all that part of the ocean west of 160° W. On t upper and middle routes between 130° and 160° W scattered fog occurred on nine days, principally betwe the 19th and the 29th. There was much lessening of f on the American coast as compared with October; b taking that part of the coast between Capes Mendoci and Conception as a whole, fog occurred on the first eig days of November and on the 20th. In the Gulf Tehuantepec it was reported on the 16th and 21st ne boundary lines of blue and green water.

TYPHOONS OF THE FAR EAST DURING SEPTEMBER AN OCTOBER, 1931

[Abstract of reports furnished by the Rev. MIGUEL SELGA, S. J., director, Weathe Bureau, Manila, P. I.]

The manuscripts descriptive of the September a October typhoons in the Asiatic section of the Nor Pacific Ocean, kindly furnished by the Rev. Miguel Selg S. J., director of the Philippine Weather Bureau, w received too late for inclusion in the September a October issues of the MONTHLY WEATHER REVIE Inasmuch as the regular North Pacific weather summari have already given brief, though necessarily incomple mention of the several typhoons of those months, t restrictions of space in the current issue allow only o brief résumé of the more important details that may drawn from the articles in hand.

Typhoons of September.—Three typhoons of low la tudes were reported. The first, a very narrow but viol storm of September 1–4, appeared off the southe China coast in the Taiwan Channel. The second, th of September 9–13, crossed the Eastern and Japan Se and disappeared north of Japan. It acquired great intensity and progressive velocity with passage of t Chosen (Korea) Strait. The third, that of Septem

18–28, was the the severest storm of the month in the lower latitudes of the Far East. It originated east of Samar, and on the 20th and 21st, moving almost due north, crossed Luzon, barely missing Manila. The lowest pressure obtained in the Philippines was 28.80 inches, at Daet, and the highest wind force, 12, from southwest, in Legaspi Bay. The storm was attended by heavy rains. A little south of 30° N. the typhoon track turned northeastward, skirted the western coast line of Japan, and the center then moved rapidly on past Sakhalin Island.

(The report does not mention among the typhoons of the month the very severe cyclone which occurred south and east of Japan from the 8th to 11th.)

Typhoons of October.—Four severe typhoons occurred in October, 1931. The storm of October 5–14 originated south-southwest of Guam, moved northwest, recurved to the northeast, and after crossing central Japan, proceeded into the open sea. "Press dispatches from Tokyo reported torrential rains and terrific winds associated with loss in life in central and western Japan. The typhoon was considered one of the worst to hit Japan in years."

The China Sea typhoon of October 9–11, which was of known hurricane force on the 10th south of Hong Kong, passed almost due west into Indo-China.

The so-called *Taurus* typhoon of October 13–20 originated between Guam and Yap. "Yet," said Father Selga, "no accurate idea of the extent and severity of the typhoon could be formed until the steamer *Taurus*, anchored at port San Vincente, reported a barometric reading of 731 millimeters (28.78 inches) and WSW. winds of force 12 at noon on October 18." The lowest barometer experienced by the *Taurus*, 28.69 inches, occurred a half hour later. The typhoon was then passing western Luzon. It headed into the China Sea, where it disintegrated on the 20th. The accompanying rainfall over northern Luzon was very heavy on the 18th. The total fall in Aparri was nearly 10 inches and gave rise to the severest flood in that region since 1908.

The typhoon of October 20–27 was first indicated as a depression south of Guam. Going northwestward, the storm gathered energy and by the 24th, when about midway between the Philippine and Bonin Islands, it began to recurve into the northeast, attaining hurricane strength for an approximate distance of 100 miles outward from the center. Here it was encountered by the M. S. *Irisbank*, which experienced winds of force 8 to 12 for 44 hours. Near the Bonins (Ogasawara) on the 26th the S. S. *Yoro Maru* was reported in distress and later to have gone ashore on one of the small islands. The *Silverhazel* proceeded to her assistance, but in 29° 25′ N., 143° 20′ E., was forced to heave to in a northwest hurricane (force 12) and in consequence had to abandon her quest. The typhoon was lost to observation on the 27th far to the eastward of Japan.—*W. E. H.*

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By Giles Slocum

STRAITS OF FLORIDA AND CARIBBEAN SEA

Table 1 shows the average temperatures for the Caribbean Sea and the Straits of Florida for November of each year from 1919 to 1930, inclusive, and Table 2 summarizes the temperature for November, 1930, in the same areas. The chart shows the number of observations taken in November, 1930, within each 1-degree square and mean temperature data for subdivisions of the area considered.

The surface water of the Caribbean Sea is warmer than the yearly mean throughout November, but autumn conditions are well established by the beginning of the month, and the temperature drop is pronounced thereafter until the end of the year and beyond. Of an annual range in temperature of approximately four and a half degrees, nearly a third of the drop from the peak in September to the minimum in March occurs in November and another third in December.

This temperature drop in the Caribbean is slightly greater in December than in November, but in the Straits the most rapid drop during the year is in November.

November, 1930, was the ninth consecutive month having above-average temperature in the Caribbean Sea, being warmer than the 11-year mean except during the first quarter when the temperature was seasonable. The fall in temperature, as the month progressed, was slower than is usual at this season, and at variance with the relatively rapid normal fall in mean temperature described above.

The Straits of Florida were unseasonably cool during the first half of the month and slightly warmer than the 11-year mean during the second half, the month as a whole being cooler than the average.

Table 1.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for November, 1919–1930*

Year	Carribbean Sea		Straits of Florida	
	Number of observations	Mean (° F.)	Number of observations	Mean (° F.)
1919 [1]	97	81.2	18	79.3
1920	146	81.5	47	78.2
1921	233	80.8	74	79.1
1922	205	81.8	78	79.6
1923	289	81.3	95	77.0
1924	259	81.7	91	77.2
1925	340	81.8	95	80.2
1926	259	82.3	127	78.5
1927	510	82.4	147	79.2
1928	539	81.8	140	79.3
1929	565	81.4	191	79.2
1930	550	82.0	129	78.2
Mean (1920–1930)		81.7		78.7

[1] Not used in computations because of insufficient data available.

Table 2.—*Mean sea-surface temperatures (°F.,) and number of observations, November, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	Nov. 1–7	136	82.1			34	77.8		
II	Nov. 8–15	135	82.1			40	78.4		
III	Nov. 16–22	132	81.9			23	78.6		
IV	Nov. 23–30	147	81.8			32	77.8		
	Month	550	82.0	+0.3	−0.9	129	78.2	−0.5	−3.0

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November, 1931

[For description of tables and charts, see REVIEW, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	60.8	+6.6	Selma	89	14	3 stations	25	7	1.76	−1.58	Riverton	4.26	Alaga	0.00
Arizona	48.8	−3.9	Granite Reef Dam	100	3	Fort Defiance	−30	24	2.57	+1.76	Natural Bridge	7.72	Yuma (weather bureau).	0.14
Arkansas	57.6	+6.2	2 stations	88	[1] 3	Dutton	18	1	6.34	+2.69	Georgetown	9.19	Portland	2.49
California	47.6	−3.9	Indio	98	3	Madeline	−12	26	2.92	+0.45	Crescent City	10.80	Greenland Ranch	0.02
Colorado	32.5	−2.9	Two Buttes	89	7	Garnett	−41	25	1.40	+0.54	Cumbres	11.45	Wray	0.10
Florida	68.5	+3.3	Venus	90	30	2 stations	30	[1] 2	0.48	−1.70	Fort Lauderdale	3.53	14 stations	0.00
Georgia	60.6	+6.0	Quitman	90	[1] 5	Blairsville	21	7	0.63	−2.10	Dahlonega	4.10	3 stations	0.00
Idaho	30.1	−4.9	Glenns Ferry	81	8	Obsidian	−27	22	1.88	−0.20	Roland	6.57	Aberdeen	0.20
Illinois	51.0	+8.9	Hillsboro	83	8	Sycamore	16	26	4.87	+2.35	2 stations	7.96	Roberts	2.47
Indiana	51.1	+8.9	Rome	83	15	2 stations	16	[1] 26	3.86	+0.76	La Porte	7.56	Bluffton	2.09
Iowa	43.9	+7.3	5 stations	81	8	do	1	29	5.76	+4.21	Guthrie Center	9.00	Inwood (near)	2.86
Kansas	46.2	+2.6	3 stations	87	[1] 7	Tribune	1	25	4.46	+3.11	Sedan	11.19	Richfield	0.15
Kentucky	55.0	+8.6	Williamsburg	84	14	Middlesboro	19	7	3.52	−0.05	Murray	6.61	Louisa	1.04
Louisiana	64.9	+6.0	2 stations	88	[1] 4	2 stations	28	1	4.84	+1.05	Ville Platte	9.98	Port Eads	1.49
Maryland-Delaware	51.8	+6.7	4 stations	80	[1] 12	Oakland, Md	16	7	0.94	−1.61	Sines, Md	2.48	Hancock (city), Md.	0.34
Michigan	44.4	+8.0	Bangor	75	[1] 23	Garnet	6	26	3.85	+1.39	Eau Claire	5.75	Painesdale	0.74
Minnesota	35.8	+6.2	Canby	81	8	Meadowlands	−12	29	2.88	+1.79	Grand Meadow	5.80	Milan	0.73
Mississippi	61.5	+6.3	Austin	89	13	West Point	25	7	4.64	+1.05	Austin	9.22	Leakesville	1.13
Missouri	52.2	+7.8	Jefferson City	87	[1] 8	Maryville	17	25	5.46	+3.06	Kidder	9.72	Shelbina	3.42
Montana	28.6	−3.3	6 stations	77	[1] 1	Ovando	−32	22	0.91	+0.09	Heron	5.21	2 stations	T.
Nebraska	38.4	+1.7	North Loup	89	8	Gordon	−6	26	2.21	+1.42	Syracuse	6.38	Hull (near)	0.19
Nevada	35.9	−4.7	Logandale	91	4	San Jacinto	−15	23	0.98	+0.27	Marlette Lake	3.81	Imlay	0.24
New England	43.7	+5.7	Brockton, Mass	80	10	Garfield, Vt	−1	27	1.33	−2.10	Pittsburg (A), N. H.	3.09	Nashua, N. H.	0.64
New Jersey	50.4	+7.4	Boonton	80	13	Layton	14	7	0.82	−2.38	2 stations	1.19	Northfield	0.42
New Mexico	40.9	−1.3	Grahams Ranch	88	1	2 stations	−36	[1] 24	1.26	+0.53	Dulce	8.44	Clayton	0.04
New York	45.8	+8.0	Geneva	79	[1] 9	Indian Lake	0	28	2.25	−0.77	High Market	4.60	Chazy	0.54
North Carolina	55.8	+5.9	Monroe	87	13	Altapass	13	7	0.84	−1.69	Rock House	3.84	3 stations	T.
North Dakota	30.3	+2.9	4 stations	78	[1] 2	3 stations	−10	[1] 21	0.55	−0.06	Grand Forks	1.77	Turtle Lake	0.00
Ohio	50.2	+8.7	Peebles	82	22	Mount Vernon	16	28	2.70	−0.10	Columbus (No. 2)	4.32	Youngstown	1.50
Oklahoma	54.1	+3.7	3 stations	89	[1] 3	Boise City	9	22	4.94	+2.92	Oklahoma City	9.63	Kenton	0.39
Oregon	36.0	−3.2	Brookings	80	3	Seneca	−30	29	3.53	−0.22	Willow Creek	16.61	Harper	0.18
Pennsylvania	49.2	+8.0	Hyndman	80	12	Mount Pocono	12	[1] 7	1.52	−1.34	Corry	4.42	Reading	0.36
South Carolina	58.8	+5.0	Darlington	87	21	Santuck	21	7	0.54	−1.75	Caesars Head	3.34	Aiken	0.00
South Dakota	34.7	+1.5	Bison	88	8	Spearfish	−12	22	0.98	+0.31	Canton	3.76	Ludlow	0.17
Tennessee	56.5	+8.1	Milan	85	13	Rugby	17	7	3.52	−0.10	2 stations	7.59	Embreeville	0.38
Texas	61.5	+4.3	Falfurrias	97	11	Romero	10	[1] 22	2.20	−0.12	Conroe	9.10	3 stations	0.00
Utah	32.3	−5.1	Springdale	84	5	Fort Duchesne	−19	[1] 24	1.54	+0.48	Silver Lake	4.77	Wendover	0.14
Virginia	53.8	+7.5	Kenbridge	87	20	Burkes Garden	14	7	0.64	−1.76	Pennington Gap	2.53	Rocky Mount	0.04
Washington	35.5	−4.1	Prosser (near)	76	1	Newport (a)	−10	27	5.00	−0.02	Big Four	22.99	Naches Heights	0.38
West Virginia	51.3	+8.6	Robertsburg	88	24	Moorefield	11	7	1.81	−1.08	New Martinsville	2.96	Moorefield	0.25
Wisconsin	41.2	+7.7	Fond du Lac	75	[1] 8	Solon Springs	0	26	4.17	+2.40	Darlington	6.13	Mellen	2.18
Wyoming	27.9	−3.2	2 stations	78	[1] 1	Riverside	−34	22	0.69	−0.06	Bechler River	3.01	Torrington	0.06
Alaska (October)	29.6	−1.1	do	62	[1] 4	Barrow	−14	28	4.34	+0.94	Yakutat	25.75	Barrow	0.03
Hawaii	72.3	+0.5	Pupukea	94	6	Kanalohuluhulu	46	[1] 15	6.72	−1.35	Honomu	33.61	3 stations	0.00
Porto Rico	76.6	−0.1	San German	96	7	Guineo Reservoir	40	15	10.89	+3.44	Paraiso	20.05	Mayaguez	2.29

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, November, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							45.9	+6.4										76	1.10	−2.1										6.4		
astport	76	67	85	30.02	30.10	+0.09	42.8	+6.1	67	22	48	20	28	37	20	40	36	78	0.94	−2.4	8	6,763	sw.	29	nw.	13	5	5	20	7.5	T.	0.0
reenville, Me.	1,070	6	----	28.91	30.10	------	38.0	------	69	10	45	11	28	31	39	----	----	----	1.10	------	6	5,134	se.	25	------	14	7	4	19	----	2.0	0.0
rtland, Me.	103	82	117	30.01	30.13	+.12	44.6	+6.6	74	10	52	22	28	38	36	39	34	73	1.24	−2.2	9	5,339	sw.	26	nw.	13	12	5	13	5.9	0.2	0.0
oncord	289	70	79	29.83	30.15	+.09	42.6	+4.9	73	10	52	10	28	33	42	----	----	----	1.05	−2.0	8	3,437	nw.	19	nw.	26	11	6	13	5.8	0.1	0.0
urlington	403	11	48	29.67	30.13	+.08	42.8	+6.5	68	10	50	17	28	36	29	----	----	----	1.59	−1.1	12	8,764	s.	37	s.	21	2	7	21	8.2	1.0	0.0
orthfield	876	12	60	29.18	30.15	+.10	40.6	+7.8	71	10	50	10	28	31	37	37	33	79	1.20	−1.7	11	5,215	s.	26	sw.	25	0	13	17	7.9	0.2	0.0
oston	125	106	165	30.02	30.16	+.11	49.4	+7.4	78	10	57	25	28	42	27	44	39	73	0.82	−2.5	6	5,139	sw.	24	nw.	6	9	9	12	5.6	T.	0.0
antucket	12	14	90	30.16	30.17	+.12	49.3	+4.9	66	24	55	34	7	44	17	46	42	78	1.68	−1.5	10	9,371	sw.	36	sw.	30	9	8	13	6.1	0.0	0.0
ock Island	26	11	46	30.14	30.17	+.11	49.2	+4.6	65	21	54	30	28	45	16	46	42	78	0.92	−2.7	7	11,134	sw.	38	nw.	6	11	7	12	5.7	0.6	0.0
ovidence	160	215	251	30.00	30.17	+.10	48.0	+7.6	72	23	56	22	8	40	26	43	39	74	0.83	−2.2	11	6,597	nw.	34	nw.	6	11	8	11	5.3	0.3	0.0
artford	159	122	----	30.00	30.18	+.10	47.7	+8.2	76	10	56	21	28	40	30	----	----	----	0.95	−2.6	7	------	sw.	----	------	----	9	7	14	6.0	1.1	0.0
ew Haven	106	74	153	30.07	30.19	+.12	48.4	+6.4	73	22	56	23	28	41	27	44	39	76	0.85	−2.5	8	4,932	n.	26	sw.	3	9	9	12	5.9	1.8	0.0
iddle Atlantic States							52.7	+7.7										.76	0.69	−1.9										5.8		
bany	97	107	115	30.06	30.17	+.09	47.2	+7.9	72	10	54	24	28	40	28	42	38	73	1.18	−1.6	8	4,975	s.	22	se.	18	8	5	17	6.4	1.6	0.0
nghamton	871	10	84	29.22	30.16	+.07	48.2	+9.5	74	23	56	19	28	40	32	----	----	----	1.21	−1.2	13	4,099	sw.	24	sw.	21	3	4	23	8.4	2.2	0.0
ew York	314	414	454	29.85	30.19	+.10	51.5	+7.3	72	13	58	30	7	45	23	46	41	73	0.61	−2.4	5	9,233	nw.	45	nw.	13	8	9	13	6.4	1.2	0.0
llefonte	1,050	5	36	29.05	30.17	------	46.8	------	74	12	58	23	7	36	42	41	38	81	0.90	------	7	------	sw.	----	------	----	5	6	19	7.4	3.0	0.0
arrisburg	374	94	104	29.79	30.20	+.09	51.2	+8.4	74	18	59	30	7	44	32	45	41	74	0.73	−1.5	6	3,761	w.	27	nw.	5	3	14	13	6.8	2.2	0.0
iladelphia	114	123	367	30.09	30.22	+.12	54.0	+8.3	74	21	60	34	27	47	23	48	42	72	1.00	−1.7	7	7,570	sw.	34	nw.	5	8	11	11	5.8	1.2	0.0
eading	325	81	103	29.85	30.21	------	51.2	+8.7	73	21	58	29	7	44	24	47	44	81	0.36	−2.4	4	3,454	w.	22	nw.	6	7	10	13	6.4	1.5	0.0
ranton	805	72	103	29.33	30.21	+.12	49.0	+8.5	72	23	57	24	7	41	32	44	40	76	0.62	−2.2	9	4,107	sw.	26	nw.	6	6	16	8	5.9	2.0	0.0
lantic City	52	37	172	30.15	30.21	+.11	52.9	+7.3	72	22	59	29	7	47	29	49	45	80	0.61	−2.2	7	9,066	w.	36	nw.	6	11	8	11	4.9	T.	0.0
ape May	17	13	49	------	------	------	53.2	+5.8	74	22	60	32	7	46	25	49	46	82	0.53	−2.7	4	------	nw.	----	------	----	7	12	11	----	0.0	0.0
ndy Hook	22	10	55	30.17	30.19	------	51.4	------	71	23	57	33	7	46	18	47	44	81	0.77	−2.5	7	8,447	sw.	37	n.	6	8	6	16	6.3	T.	0.0
enton	190	159	183	30.00	30.20	------	51.1	+6.7	75	21	59	28	7	43	27	46	42	77	0.94	−1.8	9	5,858	sw.	29	nw.	5	9	10	11	5.7	1.6	0.0
ltimore	123	100	215	30.07	30.20	+.09	54.7	+8.4	76	21	62	34	7	47	24	48	43	72	1.13	−1.4	6	5,335	sw.	32	nw.	5	11	10	9	5.5	T.	0.0
ashington	112	62	85	30.09	30.21	+.09	54.0	+8.8	77	18	63	30	7	45	29	47	43	74	1.01	−1.4	5	3,189	s.	24	nw.	25	7	11	12	6.0	T.	0.0
ape Henry	18	8	54	30.20	30.22	------	57.6	+5.5	80	19	65	36	7	51	25	52	49	79	0.21	−2.2	2	6,466	sw.	39	n.	6	12	10	8	4.6	0.0	0.0
nchburg	681	153	188	29.48	30.24	+.11	54.9	+7.7	82	16	66	26	7	44	39	48	43	73	0.45	−1.9	6	2,643	w.	22	n.	6	15	7	8	4.7	0.0	0.0
orfolk	91	170	205	30.14	30.24	+.13	59.0	+7.6	78	21	67	39	7	51	29	51	48	77	0.29	−1.9	3	6,598	s.	24	nw.	6	15	7	8	4.1	0.0	0.0
chmond	144	11	52	30.08	30.23	+.11	55.9	+7.6	79	12	67	30	7	45	36	48	44	77	0.24	−2.0	3	3,927	sw.	20	sw.	30	15	6	9	4.5	0.0	0.0
ytheville	2,304	49	55	27.82	30.23	+.10	50.5	+7.5	74	16	61	19	7	40	37	44	39	74	0.50	−1.6	5	4,186	w.	27	nw.	5	13	8	9	4.9	0.0	0.0
outh Atlantic States							60.7	+6.5										75	0.50	−1.9										4.1		
heville	2,253	89	104	27.87	30.26	+.12	53.4	+8.3	75	15	65	22	7	42	39	46	42	74	0.43	−1.8	4	4,451	se.	26	s.	20	12	6	12	5.1	0.0	0.0
arlotte	779	55	62	29.39	30.24	+.11	58.8	+8.2	81	13	69	34	7	49	32	51	47	74	0.42	−2.2	5	2,529	s.	14	sw.	30	13	10	7	4.4	0.0	0.0
eenshoro	886	5	56	29.28	20.25	------	54.2	------	78	13	67	24	7	41	42	45	42	79	0.37	------	6	3,958	sw.	19	n.	6	14	7	9	4.6	0.0	0.0
atteras	11	5	50	------	30.20	+.11	61.4	+5.1	78	19	68	45	3	55	20	58	56	90	1.17	−2.3	2	6,159	ne.	30	n.	6	15	10	5	4.0	0.0	0.0
leigh	376	103	146	29.83	30.24	+.11	58.4	+7.4	80	13	68	34	7	48	30	49	42	65	0.06	−2.2	2	4,468	sw.	19	nw.	6	15	10	5	4.1	0.0	0.0
ilmington	78	81	91	30.16	30.25	+.13	61.4	+5.4	82	13	72	37	7	51	35	53	49	75	0.15	−1.8	3	3,461	n.	18	sw.	30	16	7	7	3.7	0.0	0.0
arleston	48	11	92	30.17	30.22	+.10	63.0	+4.9	79	13	71	42	1	55	26	56	52	78	0.53	−1.6	4	5,339	n.	26	ne.	26	17	8	5	3.3	0.0	0.0
lumbia, S. C.	351	41	57	29.85	30.24	+.12	60.6	+6.6	83	13	72	33	8	49	37	51	43	63	0.52	−1.5	3	3,357	ne.	21	sw.	30	17	5	8	3.8	0.0	0.0
ue West	711	10	55	29.48	30.26	------	58.6	------	80	13	70	35	8	48	38	----	----	----	0.54	------	6	4,324	sw.	23	ne.	26	15	5	10	4.6	0.0	0.0
eenville, S. C.	1,039	139	146	29.12	30.23	------	59.0	+9.4	80	13	67	36	1	50	29	51	44	67	1.02	−2.2	7	4,410	ne.	23	ne.	26	12	9	9	4.5	0.0	0.0
igusta	182	62	77	30.01	30.21	+.08	60.9	+6.4	84	14	74	32	8	48	43	51	47	74	0.19	−2.2	2	2,155	nw.	18	se.	20	17	6	7	3.7	0.0	0.0
vannah	65	150	194	30.13	30.20	+.08	64.4	+5.9	81	14	74	40	7	55	27	56	52	76	0.04	−2.1	2	6,348	ne.	26	se.	20	16	7	7	3.6	0.0	0.0
cksonville	43	209	245	30.13	30.18	+.08	66.4	+4.2	81	30	74	39	1	58	24	60	57	81	0.97	−1.0	8	6,813	n.	27	e.	20	15	11	4	3.5	0.0	0.0
Florida Peninsula							72.7	+1.7										77	0.93	−1.3										4.7		
y West	22	10	64	30.02	30.04	+.02	74.8	+0.5	82	30	79	67	1	71	10	69	67	81	0.68	−1.5	6	7,782	ne.	23	ne.	8	17	8	5	3.9	0.0	0.0
lami	25	124	168	30.04	30.07	+.01	73.4	+1.6	80	30	78	53	1	69	16	67	64	74	2.08	−0.8	11	9,632	ne.	31	ne.	7	4	16	10	6.0	0.0	0.0
mpa	35	79	197	30.09	30.13	+.05	69.8	+2.9	86	30	80	48	1	60	26	61	58	77	0.04	−1.7	1	8,705	ne.	28	e.	22	12	17	1	3.6	0.0	0.0
tusville	44	5	----	30.09	30.14	------	71.1	------	89	30	79	50	1	63	25	----	----	----	0.58	------	6	------	nw.	----	------	----	7	19	4	5.2	0.0	0.0
East Gulf States							62.9	+6.8										75	1.62	−1.6										4.1		
lanta	1,173	190	198	28.97	30.22	+.09	59.8	+7.7	77	14	68	35	1	52	23	52	45	67	0.57	−2.5	3	5,239	e.	22	e.	26	14	5	11	4.6	0.0	0.0
acon	370	78	87	29.82	30.22	+.09	60.0	+5.8	80	14	73	32	8	47	40	51	45	71	0.21	−2.3	3	3,197	n.	17	s.	17	15	7	8	3.9	0.0	0.0
iomasville	273	49	103	29.89	30.18	+.06	64.9	+6.4	83	16	77	37	1	53	33	55	50	71	0.01	−2.7	1	4,099	ne.	17	se.	22	17	5	8	3.5	0.0	0.0
alachicola	36	11	51	30.13	30.17	------	65.6	------	81	5	73	42	1	58	26	60	58	84	0.04	−3.0	1	5,101	e.	22	o.	22	19	9	2	2.7	0.0	0.0
nsacola	56	149	185	30.11	30.17	+.06	65.6	+5.4	80	5	72	42	1	59	22	60	56	77	0.55	−3.2	4	7,953	e.	29	s.	20	16	7	7	3.8	0.0	0.0
niston	741	9	57	------	------	------	58.9	+7.0	80	13	71	28	7	47	39	----	----	----	2.89	−0.4	5	3,059	se.	20	se.	21	12	8	10	----	0.0	0.0
rmingham	700	11	48	29.43	30.20	+.08	62.3	+8.4	80	4	72	36	1	52	29	53	47	68	2.78	−0.5	5	4,089	se.	29	se.	20	17	5	8	4.1	0.0	0.0
obile	57	125	161	30.10	30.16	+.05	64.9	+6.3	79	19	74	39	1	56	29	59	57	82	0.80	−2.8	4	5,200	n.	26	nw.	20	15	5	10	4.2	0.0	0.0
ontgomery	223	100	112	29.95	30.20	+.08	62.6	+6.8	80	4	74	38	7	52	35	53	47	67	1.89	−1.3	4	3,252	e.	17	s.	17	15	8	7	3.8	0.0	0.0
rinth	469	6	----	------	------	------	59.0	------	81	11	70	28	7	48	41	----	----	----	5.03	------	10	------	se.	----	------	----	6	17	7	----	0.0	0.0
eridian	375	87	95	29.76	30.16	+.04	61.6	+7.4	81	4	73	32	7	50	38	54	50	77	2.67	−0.6	7	2,507	se.	23	w.	17	11	6	13	5.3	0.0	0.0
cksburg	247	65	73	29.88	30.17	+.05	62.9	+6.3	82	13	73	39	1	53	27	55	50	74	4.21	+0.5	8	4,242	se.	28	w.	20	12	8	10	5.0	0.0	0.0
ew Orleans	53	76	84	30.08	30.13	+.03	68.6	+7.0	82	14	76	50	2	61	21	62	60	82	2.87	−0.3	8	3,819	se.	24	nw.	20	14	6	10	4.7	0.0	0.0
West Gulf States							64.2	+6.5										77	3.00	+0.1										5.9		
reveport	249	204	220	29.84	30.11	.00	62.0	+6.0	84	4	71	41	1	54	28	56	52	76	5.01	+1.4	11	6,692	s.	32	s.	19	10	8	12	5.9	0.0	0.0
ntonville	1,303	11	44	28.69	30.07	−.04	55.4	+8.7	78	3	64	27	25	47	31	----	----	----	3.54	------	11	3,870	s.	20	se.	23	13	7	10	----	0.0	0.0
rt Smith	457	79	94	29.59	30.08	−.03	58.3	+7.3	81	3	66	35	1	50	30	52	49	76	3.12	+0.2	11	4,972	e.	24	sw.	20	9	4	17	6.3	0.0	0.0
ttle Rock	357	136	153	29.75	30.13	+.01	58.8	+6.7	79	11	66	38	1	51	30	52	48	74	8.30	+4.1	10	5,328	s.	28	w.	17	7	8	15	6.5	0.0	0.0
istin	605	136	148	29.41	30.04	------	65.0	+6.5	85	6	75	42	30	55	38	57	52	72	1.09	−1.2	11	5,396	se.	28	n.	24	7	7	16	6.8	0.0	0.0
ownsville	57	83	100	29.96	30.02	------	71.8	+4.6	89	17	80	51	25	64	30	64	61	77	0.88	−1.1	7	6,931	se.	33	n.	20	7	17	6	5.4	0.0	0.0
rpus Christi	20	11	78	30.02	30.04	−.03	70.3	+6.0	83	19	77	49	30	64	25	64	61	76	1.70	−0.3	9	7,232	se.	34	nw.	20	6	14	10	5.7	0.0	0.0
illas	512	220	227	29.52	30.07	------	61.5	------	81	4	69	38	30	54	30	----	----	----	2.38	−0.2	12	7,923	se.	48	sw.	17	9	5	16	5.9	0.0	0.0
rt Worth	670	106	114	29.33	30.05	−.05	62.0	+6.5	81	7	70	39	25	54	28	55	51	73	2.78	+0.2	11	5,785	se.	28	w.	17	9	6	15	6.0	0.0	0.0
ilveston	54	106	114	30.04	30.10	+.01	69.2	+5.9	82	5	74	51	25	64	23	64	62	81	3.74	+0.4	13	7,168	se.	30	nw.	20	11	10	9	5.0	0.0	0.0
ouston	138	292	314	29.93	30.08	------	67.6	+6.6	83	5	75	47	25	60	24	----	----	----	5.25	+1.4	12	8,927	se.	31	se.	22	9	11	10	5.6	0.0	0.0
lestine	510	64	72	29.56	30.10	−.01	63.3	+6.1	82	4	72	42	1	55	28	57	54	83	3.29	−0.1	13	4,989	s.	22	se.	16	11	3	16	5.9	0.0	0.0
rt Arthur	34	58	66	30.05	30.09	------	67.8	------	83	5	75	48	25	61	24	62	60	85	3.13	0.0	14	4,390	e.	25	s.	20	6	13	11	6.0	0.0	0.0
n Antonio	693	242	301	29.30	30.02	−.06	66.6	+6.3	84	7	75	42	30	58	31	59	55	73	0.72	−1.2	7	8,736	e.	34	e.	16	6	11	13	6.2	0.0	0.0
iylor	571	38	51	29.49	30.09	+.01	64.4	+6.7	84	13	74	40	30	54	38	----	----	----	0.64	−1.8	9	5,681	se.	26	se.	22	10	4	16	6.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, November, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0-10	In.	In
Ohio Valley and Tennessee							54.2	+9.6										75	3.21	+0.1										5.9		
Chattanooga	762	190	215	29.38	30.20	+0.06	57.8	+7.4	78	13	68	34	7	48	33	50	45	69	2.60	−0.8	9	3,637	se.	29	se.	20	13	8	9	4.5	0.0	0.(
Knoxville	995	102	111	29.15	30.22	+.09	55.6	+7.7	77	22	66	32	7	45	34	49	44	73	1.93	−1.1	8	2,922	sw.	26	s.	17	14	8	8	4.2	0.0	0.(
Memphis	399	76	97	29.72	30.15	+.03	58.8	+7.1	80	13	66	37	25	51	25	52	47	72	6.31	+2.1	9	4,419	s.	20	w.	17	12	6	12	5.3	T.	0.(
Nashville	546	168	191	29.61	30.20	+.08	57.8	+8.8	79	13	68	32	7	48	33	51	46	72	3.75	+0.2	10	5,373	s.	46	se.	20	14	5	11	4.9	0.0	0.(
Lexington	989	193	230	29.14	30.22	+.10	54.8	+10.0	76	22	62	28	26	47	29				2.50	−0.8	12	8,416	sw.	38	s.	20	9	8	13	5.9	T.	0.(
Louisville	525	188	234	29.60	30.18	+.06	55.4	+8.7	77	16	63	30	26	48	29	49	45	73	3.38	−0.2	11	6,636	s.	39	sw.	20	8	6	16	6.2	0.0	0.(
Evansville	431	76	116	29.68	30.16	+.04	55.6	+9.0	78	16	63	32	25	48	28	50	46	76	4.65	+0.9	12	6,052	s.	28	sw.	12	10	8	12	5.4	0.0	0.(
Indianapolis	822	194	230	29.24	30.14	+.04	51.7	+9.4	75	14	59	26	26	45	29	46	42	75	3.38	0.0	14	7,455	s.	31	sw.	17	9	7	14	6.4	2.9	0.(
Royal Center	735	11	55	29.31	30.12		48.8		73	16	57	20	26	40	34				2.94	+0.3	12	6,781	s.	32	sw.	20	6	9	15	6.7	1.7	0.(
Terre Haute	575	96	129	29.51	30.13		52.5		77	14	60	27	26	45	33	47	43	77	4.27	+1.0	13	6,203	s.	29	se.	20	9	6	15	6.2	5.5	0.(
Cincinnati	627	11	51	29.50	30.18	+.06	53.7	+11.2	76	16	61	26	26	46	30	47	43	75	3.01	+0.2	16	4,525	sw.	26	se.	20	7	9	14	6.3	2.0	0.(
Columbus	822	216	230	29.29	30.17	+.06	51.4	+9.5	74	22	59	25	26	44	27	46	42	76	3.64	+0.9	17	7,149	s.	31	w.	5	6	10	14	6.5	3.1	0.(
Dayton	899	137	173	29.20	30.17		52.0	+10.0	74	14	59	25	26	45	29	46	43	77	3.41	+0.6	16	5,655	sw.	30	s.	20	6	15	9	6.5	5.3	0.(
Elkins	1,947	59	67	28.16	30.25	+.13	49.8	+9.5	73	19	61	19	7	39	38	44	41	80	1.87	−0.9	11	3,406	w.	22	s.	20	6	10	14	6.7	T.	0.(
Parkersburg	637	77	82	29.55	30.22	+.10	53.2	+9.4	78	20	62	24	26	44	29	46	42	74	1.97	−0.6	15	3,250	se.	24	nw.	5	7	7	16	6.7	T.	0.(
Pittsburgh	842	353	410	29.27	30.19	+.09	51.6	+8.4	75	20	59	26	26	44	29	46	41	74	1.80	−0.5	13	6,509	w.	36	w.	5	5	11	14	6.5	2.5	0.(
Lower Lake Region							48.4	+9.1										75	2.34	−0.4										7.5		
Buffalo	767	247	280	29.26	30.10	+.05	47.9	+8.5	69	20	54	28	26	42	22	44	41	78	1.71	−1.3	14	12,818	sw.	56	w.	3	2	7	21	7.7	0.9	0.(
Canton	448	10	61	29.60	30.09		42.4	+8.5	71	17	50	18	27	34	32				2.12	−1.0	14	6,749	sw.	35	w.	25	1	10	19	7.8	0.4	0.(
Ithaca	836	74	100	29.23	30.15		48.7	+10.1	74	10	57	14	28	40	29	43	38	74	1.07	−1.3	13	6,940	s.	32	s.	21	2	8	20	7.8	2.6	0.(
Oswego	335	71	85	29.74	30.12	+.07	48.2	+9.3	73	23	55	20	28	41	33	43	38	74	1.92	−1.5	14	7,512	s.	26	w.	25	0	8	22	8.2	1.0	0.(
Rochester	523	86	102	29.55	30.13	+.08	49.1	+10.4	74	23	56	27	28	42	25	44	39	72	1.91	−0.6	14	5,666	sw.	27	sw.	3	2	9	19	7.8	0.9	0.(
Syracuse	596	65	79	29.49	30.14	+.08	48.6	+9.9	75	23	56	17	28	41	32				2.38	−0.4	15	4,700	s.	19	nw.	5	2	9	19	8.0	4.8	0.(
Erie	714	130	166	29.34	30.12	+.06	50.1	+8.7	74	23	56	25	28	41	28	45	42	75	2.79	−0.5	15	10,396	s.	42	sw.	5	3	13	14	7.1	1.1	0.(
Cleveland	762	267	337	29.30	30.13	+.06	51.2	+10.3	75	23	58	28	28	45	30	45	40	70	2.48	−0.2	14	9,911	s.	46	w.	5	3	8	19	7.9	3.1	0.(
Sandusky	629	5	67	29.45	30.15	+.07	49.5	+8.4	74	23	57	24	28	42	29				2.08	−0.3	13	6,366	sw.	27	w.	24	3	11	16	7.3	4.0	0.(
Toledo	628	208	243	29.44	30.14	+.07	48.9	+8.5	71	23	55	26	26	42	32	44	40	76	3.38	+1.0	11	9,334	sw.	36	w.	24	7	11	12	6.3	1.5	0.(
Fort Wayne	856	110	119	29.19	30.13		49.2	+8.6	71	23	56	24	26	42	31	44	41	80	2.64	−0.2	11	6,670	s.	32	se.	20	7	7	16	7.2	2.3	0.(
Detroit	730	218	258	29.32	30.12	+.06	47.8	+8.5	70	20	54	26	26	42	26	44	40	77	3.56	+1.1	12	7,197	sw.	33	sw.	12	5	8	17	7.3	0.7	0.(
Upper Lake Region							44.1	+8.7										79	3.57	+1.1										7.2		
Alpena	609	13	92	29.35	30.02	+.01	43.6	+9.2	68	9	51	22	26	36	30	40	36	78	3.33	+0.7	17	8,486	sw.	38	sw.	20	4	12	14	6.7	0.3	0.(
Escanaba	612	54	60	29.32	30.00	−.03	41.4	+8.3	60	10	48	16	26	35	28	38	34	78	3.02	+0.9	12	6,698	s.	34	sw.	20	8	8	14	6.1	T.	T.
Grand Haven	632	54	89	29.36	30.05	+.01	46.5	+8.0	67	16	53	26	25	40	32	44	40	78	3.85	+1.1	12	9,777	s.	38	sw.	24	5	4	21	7.6	T.	0.(
Grand Rapids	707	70	244	29.29	30.07	+.02	47.6	+9.2	73	9	55	27	25	40	33	43	39	76	3.27	+0.5	10	9,326	s.	44	sw.	24	3	8	19	7.6	T.	0.
Houghton	668	64	99	29.20	29.94	−.08	40.7	+8.7	69	9	47	22	26	35	32				2.83	−0.2	17	6,950	e.	45	w.	24	5	4	21	8.0	2.9	1.
Lansing	878	6	88	29.12	30.08		45.6	+8.1	71	9	53	22	26	38	34	42	40	87	3.35	+0.9	13	6,980	sw.	32	s.	20	5	3	22	7.7	T.	T.
Ludington	637	60	66	29.32	30.03		45.6	+8.2	65	20	51	26	25	40	33	43	40	80	3.20	+0.5	12	9,491	s.	41	sw.	20	6	9	15	6.7	T.	0.
Marquette	734	77	111	29.14	29.96	−.06	42.2	+8.9	69	9	49	20	26	36	36	38	34	75	3.34	+0.4	16	7,560	w.	39	sw.	24	6	3	21	7.7	1.5	0.
Port Huron	638	70	120	29.38	30.09	+.04	46.4	+8.9	69	23	53	24	26	39	25	42	39	79	2.25	−0.1	11	7,973	s.	30	nw.	5	2	12	16	7.0	0.4	0.
Sault Sainte Marie	614	11	52	29.29	30.00	−.01	40.7	+8.7	66	9	47	20	26	35	32	38	35	82	4.71	+2.0	20	6,942	se.	42	nw.	3	3	8	19	7.7	5.3	1.
Chicago	673	7	131	29.35	30.08	+.01	50.0	+9.9	73	9	56	24	25	44	37	45	41	74	4.63	+2.3	11	7,331	sw.	32	sw.	24	6	9	15	6.6	0.2	0.
Green Bay	617	109	141	29.34	30.01	−.03	43.2	+9.2	67	9	50	17	26	36	41	39	36	78	3.61	+1.4	10	7,667	s.	42	s.	20	6	8	16	7.1	0.3	0.
Milwaukee	681	125	221	29.30	30.04	−.01	47.1	+9.8	72	9	54	22	26	40	38	43	39	76	4.65	+2.9	9	9,399	w.	43	s.	20	6	11	13	6.4	T.	0.
Duluth	1,133	5	47	28.70	29.95	−.09	36.2	+6.2	65	8	44	7	26	28	32	32	29	80	3.89	+2.4	15	8,104	w.	39	sw.	24	4	6	20	7.4	4.0	0.
North Dakota							30.8	+3.9										78	0.62	−0.1										5.7		
Moorhead	940	50	58	28.94	29.98	−.09	33.0	+5.9	69	8	42	1	29	24	34	29	26	83	1.57	+0.7	7	5,563	s.	28	nw.	24	7	8	15	6.4	11.1	6.
Bismarck	1,674	8	57	28.18	30.02	−.05	31.1	+2.6	74	2	40	3	28	22	39	26	22	77	0.25	−0.3	4	5,115	nw.	29	nw.	21	14	7	9	4.6	4.2	2.
Devils Lake	1,478	11	44	28.37	29.99	−.07	29.9	+5.4	68	8	38	2	25	22	31	26	23	83	0.48	−0.2	6	5,971	nw.	28	nw.	24	7	11	12	6.3	5.1	3.
Ellendale	1,457	10	56	28.41	30.01		30.8		72	7	41	−2	25	20	42				0.73	0.0	8	8,199	nw.	41	nw.	24	9	8	13	5.9	6.5	6.
Grand Forks	833	12	67				31.3		69	8	40	−4	25	23	33	27			1.77		4		se.	44	nw.	24	13	3	14		10.9	10.
Williston	1,878	41	48	27.98	30.03	−.03	29.0	+1.8	68	6	40	−2	27	18	37	24	18	71	0.05	−0.5	3	4,644	sw.	30	w.	6	14	5	11	5.1	0.7	0.
Upper Mississippi Valley							47.6	+9.2										78	49.7	+3.0										6.6		
Minneapolis	918	102	208	28.96	29.96		40.3	+7.9	68	16	48	12	29	33	28				3.29	+2.0	15	6,891	w.	34	w.	24	7	8	15	6.6	0.7	T
St. Paul	837	114	149	29.06	29.99	−.07	40.3	+7.8	68	16	48	11	29	33	31				2.94	+1.6	16	5,630	sw.	30	w.	24	6	9	15	6.5	1.7	T
La Crosse	714	11	48	29.23	30.02	−.05	43.2	+8.0	69	16	52	16	26	34	41	39	36	82	4.78	+3.2	13	3,594	s.	31	sw.	20	5	10	15	6.9	0.3	0.
Madison	974	70	78	28.98	30.04	−.02	44.8	+9.6	70	16	52	19	25	38	39	40	37	79	5.48	+3.7	9	6,399	w.	30	sw.	20	7	9	14	0.7	T.	0.
Wausau	1,247	4	62	28.64	30.00		40.0		68	8	48	14	26	32	37				4.22	+2.4	9	4,560	w.	24	sw.	24	5	4	21	8.0	T	T
Charles City	1,015	10	51	28.94	30.04	−.04	41.4	+8.4	75	8	50	14	25	32	35	38	36	84	8.11	+6.6	10	4,734	se.	27	sw.	20	9	6	15	6.4	T	0.
Davenport	606	118	143	29.40	30.07	−.01	48.8	+9.8	76	16	56	20	25	41	37	43	39	76	4.99	+3.2	12	7,473	sw.	37	sw.	20	6	7	17	7.0	0.5	0.
Des Moines	861	5	99	29.12	30.04	−.04	45.0	+6.6	78	8	54	18	25	36	37	41	38	81	7.10	+5.7	13	6,115	s.	33	nw.	9	5	5	20	7.5	2.2	T
Dubuque	700	81	96	29.29	30.05	−.02	45.8	+8.8	73	16	54	17	25	38	40	41	38	79	4.86	+3.2	11	3,935	s.	22	nw.	17	5	9	16	6.8	T.	0.
Keokuk	614	64	78	29.41	30.10	+.01	51.0	+9.9	78	8	59	23	25	43	35	45	41	74	3.85	+1.9	13	5,015	s.	27	s.	20	11	3	16	6.2	1.0	0.
Cairo	358	87	93	29.76	30.14	+.02	56.6	+9.3	78	16	64	32	25	49	28	50	45	73	5.35	+1.7	10	5,385	s.	25	sw.	17	9	5	16	6.3	0.0	0.
Peoria	609	11	45	29.43	30.10	+.01	50.2	+12.7	78	8	59	23	25	42	36	44	41	79	5.55	+3.2	13	4,513	s.	25	sw.	20	11	4	15	6.0	0.7	0.
Springfield, Ill.	636	5	91	29.41	30.10	.00	52.0	+9.8	78	8	60	26	25	44	34	46	42	76	5.07	+2.6	11	8,545	s.	39	s.	20	9	5	16	6.3	2.8	0.
Hannibal	534	74	109	29.51	30.09	.00	52.6	+10.5	80	8	60	26	25	45	31				4.29	+2.2	12	6,093	sw.	31	sw.	20	8	6	10	6.1	3.0	0.
St. Louis	568	265	303	29.49	30.10	.00	54.8	+9.7	82	8	63	30	25	47	35	48	43	72	4.65	+1.8	13	8,472	sw.	44	sw.	14	11	7	12	5.6	0.3	0.
Missouri Valley							44.3	+5.3										74	4.58	+3.2										5.8		
Columbia, Mo.	781	6	84	29.24	30.08	−.01	52.8	+9.5	80	8	61	26	25	44	31				3.94	+1.7	12	5,224	s.	31	sw.	20	9	6	15	6.1	2.9	0.
Kansas City	963	161	181	29.02	30.07	−.02	50.6	+6.9	79	8	58	28	24	43	30	46	42	75	9.52	+7.7	14	5,376	s.	39	sw.	23	10	3	17	6.4	2.0	0.
St. Joseph	967	11	49	29.00	30.05		49.0		80	8	58	23	25	40	32	44	41	80	8.35	+6.7	15	5,221	se.	30	nw.	9	10	5	15	5.9	0.5	0.
Springfield, Mo.	1,324	98	104	28.66	30.08	−.02	54.3	+8.6	79	3	62	26	25	47	28	48	43	73	4.08	+1.3	14	7,081	s.	30	s.	23	12	8	10	4.9	0.6	0.
Iola	984	11	50	28.99	30.05	−.04	51.4	+7.3	80	8	61	25	25	42	35				8.13	+6.3	15	3,982	s.	20	sw.	20	9	4	17	6.6	2.1	0.
Topeka	987	92	107				49.1	+6.3	80	8	58	25	24	40	35				7.07	+5.6	13	5,544	sw.	29	sw.	9	10	2	18	6.1	1.8	0.
Lincoln	1,189	11	81	28.75	30.04	−.04	43.8	+4.7	80	8	53	20	29	35	39	39	35	77	5.60	+4.5	10	5,845	s.	26	nw.	11	8	7	15	6.3	4.2	T
Omaha	1,105	115	122	28.84	30.04	−.04	44.6	+6.1	80	8	53	17	29	36	31	39	35	74	5.07	+4.0	10	4,303	s.	23	n.	3	10	7	13	5.8	4.7	T
Valentine	2,598	47	54	27.28	30.06	−.02	35.4	+0.8	81	8	49	0	29	22	46	27	21	67	0.40	−0.2	4	5,164	w.	27	nw.	21	11	8	11	5.3	5.1	2.
Sioux City	1,135	94	104	28.78	30.02	−.06	40.6	+5.4	78	8	49	8	29	32	42	36	32	78	4.00	+3.0	14	6,920	nw.	34	s.	16	6	10	14	6.3	3.0	0.
Huron	1,306	59	74	28.60	30.03	−.05	34.4	+2.9	79	8	45	−1	29	24	43	30	25	74	0.56	0.0	7	5,533	se.	31	nw.	20	12	8	10	5.0	3.4	1.
Pierre	1,572	70	75	28.31	30.03	−.05	35.4	+1.8	81	8	47	8	28	24	44	29	22	66	0.54	+0.1	5	4,869	nw.	34	nw.	20	12	9	9	4.9	7.6	3.
Yankton	1,233	49	57	28.64	30.05	−.03	39.1	+3.8	80	8	49	6	29	29	42				2.23	+1.4	10	4,244	nw.	26	s.	16	9		12	6.1	5.6	4.

TABLE 1.—*Climatological data for Weather Bureau stations, November, 1931*—Continued

…trict and station	Elevation of instruments			Pressure			Temperature of the air										Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							30.3	−2.4										69	0.86	+0.2										6.0		
Bl ngs	3,140	5					32.2	------	77	2	44	−6	27	20	40	----	----	----	0.72	------	5	------	nw.	----	----	----	11	8	11	----	8.4	4.0
H re	2,505	11	44	27.35	30.06	+0.03	26.4	−4.8	73	1	38	−20	22	15	45	22	17	71	0.57	0.0	7	6,366	sw.	36	w.	2	10	7	13	5.9	9.5	5.5
H na	4,110	87	112	25.78	30.09	−.01	29.4	−3.8	70	7	38	−6	22	21	30	24	18	66	0.84	+0.1	9	4,144	sw.	26	sw.	18	6	13	11	6.2	16.1	7.1
K spell	2,973	48	56	26.96	30.11	+.04	27.2	−5.2	62	6	35	−9	22	19	32	26	23	85	2.57	+1.2	14	2,985	nw.	26	sw.	14	2	8	20	7.8	31.3	8.7
M s City	2,371	48	55	27.47	30.09	+.02	31.8	+0.9	76	2	43	−2	27	21	43	26	20	72	0.54	0.0	7	3,661	s.	34	nw.	20	11	8	11	5.7	7.7	2.8
R d City	3,259	50	58	26.57	30.07	−.01	36.2	+0.3	77	7	48	6	21	25	38	28	20	61	0.44	0.0	4	4,700	w.	30	nw.	23	12	8	10	4.9	4.9	1.8
…yenne	6,088	84	101	23.95	30.06	−.01	32.8	−2.0	71	2	44	−6	22	21	35	25	16	56	0.40	−0.1	5	7,888	w.	44	w.	17	16	5	9	3.9	5.4	0.5
L ler	5,372	60	68	24.61	30.12	+.02	27.2	−3.1	70	2	40	−13	29	15	39	22	16	70	0.77	+0.2	4	2,617	sw.	30	s.	15	17	8	5	3.5	7.2	5.5
…idan	3,790	10	47	26.06	30.07	------	31.4	------	74	6	44	−3	27	19	45	25	19	68	0.67	0.0	9	2,464	nw.	28	sw.	16	11	11	8	5.3	5.1	1.8
Y…wstone Park	6,241	11	48	------	30.15	+.04	24.6	−4.7	62	5	34	−12	21	15	31	----	----	74	1.24	0.0	12	5,060	sw.	35	sw.	8	8	8	14	----	22.2	9.8
N h Platte	2,821	11	51	27.05	30.05	−.03	37.4	+0.8	80	7	50	9	25	24	47	29	21	63	0.59	+0.1	4	3,974	w.	20	nw.	20	11	8	11	5.1	6.2	2.6
Middle Slope							44.6	+1.8										68	3.46	+2.5										5.0		
D ver	5,292	106	113	24.69	30.04	−.02	37.6	−2.2	78	2	49	0	22	27	35	28	17	51	0.59	0.0	8	4,400	s.	29	sw.	17	18	6	6	3.5	15.6	3.4
P blo	4,685	80	86	25.27	30.04	−.01	37.3	−2.1	78	2	52	2	25	23	50	29	18	52	0.42	+0.1	6	3,429	nw.	29	nw.	20	16	7	7	4.1	5.4	1.1
C cordia	1,392	50	58	28.56	30.07	−.01	45.0	+3.6	81	8	54	20	30	36	37	40	36	80	2.61	+1.6	11	4,476	sw.	26	sw.	9	13	5	12	5.2	4.9	0.7
D ge City	2,509	88	100	27.42	30.06	−.01	44.4	+1.8	82	8	55	17	22	34	46	37	32	74	1.32	+0.6	8	8,096	nw.	37	nw.	9	15	5	10	4.7	2.9	T.
W ita	1,358	139	158	28.58	30.03	−.05	49.4	+4.6	79	8	58	27	24	41	28	44	39	74	6.21	+4.8	13	7,256	s.	44	s.	9	9	6	15	6.2	3.0	0.0
O homa City	1,214	10	47	28.75	30.05	−.03	53.8	+5.0	82	3	63	30	30	45	31	48	44	76	9.63	+7.8	10	5,678	s.	24	w.	16	8	7	15	6.3	T.	0.0
Southern Slope							54.5	+2.7										67	1.85	+0.8										5.1		
A ene	1,738	10	52	28.22	30.03	−.04	57.8	+4.3	79	7	67	33	30	49	32	51	47	74	3.49	+2.1	10	6,059	s.	30	s.	16	12	3	15	5.8	0.0	0.0
A rillo	3,676	10	49	26.27	30.03	−.02	47.0	+1.5	84	3	58	16	22	36	38	39	34	70	2.89	+2.0	10	5,202	s.	21	s.	8	12	9	9	4.8	8.2	0.0
D Rio	944	64	71	28.99	29.98	−.07	64.4	+4.4	84	23	74	38	20	55	36	56	50	66	0.64	−0.6	7	6,038	se.	29	nw.	16	12	5	13	5.7	0.0	0.0
R vell	3,566	75	85	26.37	30.01	−.02	48.7	+0.6	80	3	63	24	27	34	46	39	30	57	0.38	−0.5	5	4,319	s.	30	nw.	19	13	12	5	4.2	0.7	0.0
…outhern Plateau							47.3	−1.9										60	1.08	+0.6										3.7		
E aso	3,778	152	175	26.17	29.97	−.03	54.0	+1.3	81	3	66	32	30	42	37	42	31	47	0.64	+0.1	5	6,402	w.	42	w.	28	17	6	7	3.6	2.0	2.0
A iquerque	4,972	51	66	25.04	29.99	------	42.2	------	74	3	55	5	24	30	40	34	27	61	1.19	------	7	3,291	ne.	31	se.	21	11	13	6	4.5	4.6	T.
S a Fe	7,013	38	53	23.21	30.02	−.01	37.1	−1.8	67	2	47	2	24	27	30	29	23	64	1.16	+0.5	10	4,224	n.	32	se.	22	14	7	9	4.4	11.3	2.8
F staff	6,907	10	59	23.28	29.96	−.06	32.4	−2.2	69	3	44	−5	29	21	42	27	----	80	2.57	------	15	4,564	sw.	26	sw.	15	6	14	10	----	14.0	3.0
P enix	1,108	10	107	28.80	29.96	−.02	57.2	−2.5	94	3	68	27	23	46	40	47	39	58	3.18	+2.5	8	2,744	e.	19	sw.	21	20	4	6	3.6	0.0	0.0
Y na	141	9	54	29.83	29.98	.00	58.8	−3.6	93	4	71	31	23	46	38	48	38	51	0.14	−0.2	4	3,217	n.	22	n.	29	22	5	3	2.2	0.0	0.0
In pendence	3,957	6	27	25.96	30.04	−.01	44.4	−2.8	78	3	58	11	23	31	38	33	----	----	0.29	0.0	1	------	nw.	----	------	----	20	3	7	----	T.	0.0
Middle Plateau							34.9	−4.3										64	1.33	+0.6										4.4		
R o	4,532	74	81	25.47	30.07	−.04	38.6	−2.4	77	3	51	10	23	26	41	32	23	59	0.43	−0.2	6	3,567	sw.	30	sw.	17	14	8	8	4.1	3.4	0.0
T opah	6,090	12	20	------	------	------	35.4	------	69	1	43	2	22	28	22	28	20	60	0.66	------	5	------	se.	----	------	----	----	----	----	----	----	----
W nemucca	4,344	18	56	25.64	30.12	−.02	32.6	−5.8	75	4	47	0	23	18	49	27	20	66	0.80	+0.1	7	4,689	ne.	24	nw.	8	15	6	9	4.5	4.8	0.1
M lena	5,473	10	43	24.59	30.05	−.03	30.7	−5.7	73	3	44	−11	23	18	45	25	19	71	2.17	+1.6	9	5,134	w.	27	sw.	10	14	3	13	4.5	14.8	3.2
S Lake City	4,360	163	203	25.63	30.08	−.04	36.2	−4.9	74	6	44	9	24	28	29	30	22	58	1.95	+0.6	10	4,332	s.	33	s.	14	15	5	10	4.2	14.6	2.3
G nd Junction	4,602	60	68	25.38	30.02	−.06	36.6	−2.7	69	3	47	3	25	26	37	30	25	70	1.31	+0.7	11	2,855	nw.	20	s.	16	14	6	10	4.6	7.8	0.8
…orthern Plateau							35.3	−4.1										71	1.46	+0.1										6.5		
B er	3,471	48	53	26.46	30.13	−.03	31.0	−5.0	65	1	40	−2	30	22	32	27	21	68	1.53	+0.5	14	3,743	se.	22	w.	7	8	9	13	6.0	15.3	4.8
B e	2,739	79	87	27.22	30.14	−.03	36.7	−4.3	72	6	46	8	22	27	34	31	25	68	1.38	+0.1	8	3,049	se.	22	se.	13	11	7	12	5.6	7.3	1.6
L iston	757	40	48	29.29	30.13	+.01	37.9	−3.5	67	1	44	15	22	31	26	----	----	----	1.19	−0.4	14	2,200	e.	18	sw.	8	2	8	20	8.0	1.2	T.
P tello	4,477	60	68	25.49	30.12	−.02	32.8	−3.9	71	2	42	−1	22	24	37	28	22	72	0.85	0.0	7	5,980	se.	31	sw.	18	7	13	10	5.4	10.6	3.0
P o	416	5	33	------	------	------	37.3	------	72	1	46	6	26	28	39	----	----	73	1.47	------	7	5,356	nw.	----	------	----	5	7	18	----	5.3	3.5
S kane	1,929	101	110	28.01	30.11	+.01	33.3	−5.2	66	1	40	4	28	26	28	31	27	77	2.41	+0.3	13	3,438	s.	24	sw.	19	7	5	18	6.6	13.9	3.4
W la Walla	991	57	65	29.02	30.11	−.02	38.8	−4.0	70	1	45	12	30	33	28	35	31	73	2.38	+0.4	10	2,805	s.	23	se.	9	3	11	16	7.6	4.3	3.4
Y ima	1,076	58	67	28.93	30.11	------	36.4	−2.5	65	6	46	7	28	27	30	32	25	66	0.48	−0.4	5	2,713	nw.	26	sw.	19	9	5	16	6.2	2.1	0.2
…orth Pacific Coast Region							43.8	−2.4										81	5.17	−0.9										6.8		
… th Head	211	11	56	29.82	30.06	+.01	45.2	−3.0	66	4	50	33	22	40	18	43	39	81	7.04	−1.4	17	9,216	n.	56	s.	6	10	0	20	6.9	0.0	0.0
P Angeles	29	8	53	------	30.06	------	41.8	------	55	1	48	27	21	36	18	----	----	----	3.62	−0.3	15	3,785	s.	27	w.	19	4	12	14	----	T.	0.0
S tle	125	215	250	29.91	30.04	.00	43.2	−2.4	59	4	48	29	30	39	16	41	37	78	2.66	−2.4	15	5,836	s.	33	s.	19	8	5	17	6.5	0.0	0.0
T oma	194	172	201	29.84	30.06	+.02	42.4	−2.2	61	1	48	23	30	37	17	----	----	----	2.74	−3.5	14	5,724	s.	36	sw.	19	5	7	18	7.3	T.	0.0
T oosh Island	86	9	53	29.92	30.02	+.05	44.8	−1.1	59	4	48	35	16	42	10	43	41	87	11.28	−0.6	16	10,408	e.	55	s.	18	5	7	18	7.0	0.6	0.0
M ford	1,329	29	58	28.67	30.11	------	40.8	------	73	1	51	19	23	31	33	38	34	81	3.12	+0.6	11	1,920	nw.	29	nw.	7	10	6	14	5.9	0.8	0.0
P tland, Oreg	153	68	106	29.92	30.09	−.01	44.0	−2.8	67	1	50	25	30	38	21	40	36	76	6.38	+0.3	14	4,125	se.	24	sw.	19	8	1	21	6.9	0.0	0.0
R eburg	510	75	99	29.55	30.11	−.01	43.2	−2.7	70	1	50	22	23	37	24	41	38	83	4.51	−0.2	13	2,225	s.	18	s.	19	4	10	16	7.1	0.0	0.0
M dle Pacific Coast Region							50.9	−2.9										66	2.74	0.0										3.7		
E eka	62	73	89	30.04	30.12	+.01	47.0	−4.1	67	3	54	30	22	40	21	45	43	86	5.75	+0.6	15	3,483	se.	28	n.	20	14	4	12	4.6	0.0	0.0
R Bluff	330	5	58	29.70	30.06	−.05	51.6	−2.2	82	3	62	29	23	41	35	43	33	56	1.93	−1.0	7	4,389	nw.	29	s.	13	16	6	8	3.7	0.0	0.0
R lding	722	20	34	------	------	------	51.8	------	83	3	61	30	22	43	29	----	----	52	3.76	------	6	5,252	nw.	----	------	----	15	8	7	----	0.0	0.0
S amento	69	106	117	29.97	30.04	−.05	50.6	−3.0	83	6	60	28	23	41	33	45	39	68	1.30	−0.6	8	4,672	se.	24	n.	21	20	5	5	2.7	0.0	0.0
S Francisco	155	208	243	29.88	30.05	−.04	54.4	−1.9	80	6	61	39	23	48	25	48	42	70	2.93	+0.6	10	4,398	w.	34	n.	21	16	6	8	3.8	0.0	0.0
S Jose	141	12	110	29.92	30.07	------	51.0	−3.4	82	7	62	28	24	40	34	----	----	----	1.79	+0.3	7	3,452	nw.	23	se.	14	16	6	8	3.7	0.0	0.0
…outh Pacific Coast Region							56.2	−2.0										63	1.89	+0.9										3.7		
F sno	327	89	98	29.69	30.05	−.01	52.8	−1.4	86	4	63	28	22	42	34	45	36	59	1.76	+0.8	5	3,023	nw.	24	nw.	8	17	7	6	3.3	T.	0.0
L Angeles	338	159	191	29.65	30.02	.00	58.7	−2.2	87	4	67	40	24	50	32	49	41	59	1.95	+0.8	3	3,207	ne.	19	nw.	21	16	7	7	3.5	0.0	0.0
S Diego	87	62	70	29.91	30.00	−.02	57.2	−2.5	81	4	65	38	24	50	28	52	47	72	1.95	+1.2	7	3,572	e.	24	se.	15	13	8	9	4.4	0.0	0.0
West Indies																																
… Juan, P. R.	82	9	54	29.79	29.87	------	78.6	+0.2	89	9	83	68	18	74	14	----	----	----	15.64	+8.9	24	6,408	s.	35	e.	16	1	23	6	6.2	0.0	0.0
Panama Canal																																
B oa Heights	118	6	97	29.73	[1] 29.81	−0.1	78.0	−1.1	88	17	83	70	9	73	16	----	----	[1] 88	12.60	+2.4	26	4,194	nw.	24	s.	1	0	5	25	8.4	0.0	0.0
C stobal	36	6	97	29.79	[1] 29.82	−0.1	79.1	−0.2	88	6	84	72	8	75	12	75	74	[1] 85	30.31	+9.1	27	6,345	w.	37	w.	8	1	8	21	8.3	0.0	0.0
Alaska																																
F rbanks	455	11	44	[2] 29.28	[2] 29.84	------	9.0	------	42	4	18	−29	19	0	44	11	8	88	0.38	------	10	1,252	n.	14	w.	12	6	7	17	6.9	6.7	6.7
J eau	80	11	50	[2] 29.86	[2] 29.95	------	33.6	------	47	5	37	16	20	30	12	32	28	80	7.76	------	20	4,115	s.	27	e.	14	6	1	23	7.6	5.6	0.0
Hawaiian Islands																																
…nolulu	38	86	100	[2] 29.95	[2] 29.99	------	75.0	+0.5	81	7	79	63	29	71	14	69	66	75	1.02	−2.8	12	5,737	c.	24	e.	8	6	17	7	5.7	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, November, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature: Departure from normal	Temperature: Mean maximum	Temperature: Mean minimum	Temperature: Highest	Temperature: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				38.9		45.1	32.7	54	16	3.94		0.1
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20												
Quebec, Que.	296	29.72	30.05	+.03	37.9	+8.9	44.1	31.8	64	16	1.89	−1.87	3.
Doucet, Que.	1,236				31.0		38.9	23.1	60	6	2.95		13.
Montreal, Que.	187	29.83	30.04	+.01	41.5	+9.7	47.7	35.4	67	22	2.68	−1.06	1.
Ottawa, Ont.	236	29.80	30.07	+.05	41.1	+9.4	49.5	32.7	67	18	2.03	−0.51	1.
Kingston, Ont.	285	29.79	30.11	+.07	44.4	+9.4	50.1	38.7	62	24	2.40	−0.84	T.
Toronto, Ont.	379	29.68	30.09	+.05	45.8	+10.2	51.8	39.8	66	28	2.44	−0.70	0.
Cochrane, Ont.	930				32.6		39.2	26 1	63	12	4.49		13.
White River, Ont.	1,244	28.57	29.91	−.07	32.7	+12.2	40.7	24.8	64	8	6.43	+4.58	5.
London, Ont.	808				44.4		51.9	36.8	69	24	2.72		0.
Southampton, Ont.	656	29.33	30.06	+.04	44.9	+9.9	51.5	38.3	70	24	4.67	+0.97	3.
Parry Sound, Ont.	688	29.34	30.04	+.03	42.0	+9.9	48.0	36.0	63	20	3.88	−0.49	1.
Port Arthur, Ont.	644	29.21	29.92	−.08	37.0	+13.0	43 2	30.8	54	16	3.47	+2.14	0.
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.10	29.97	−.07	24.6	+7.3	32.9	16.4	61	−2	0.11	−0.89	0.
Le Pas, Man.	860				20.3		28.8	11.9	48	−9	0.70		7.
Qu'Appelle, Sask.	2,115	27.64	29.95	−.05	22.8	+4.0	32.0	13.6	59	−14	0.64	−0.25	6.
Moose Jaw, Sask.	1,759				25.0		36.1	13.8	65	−11	0.34		3.
Swift Current, Sask.	2,392	27.36	29.97	−.05	25.4	+2.2	35.2	15.7	72	−16	0.54	−0.15	5.
Medicine Hat, Alb.	2,365												
Calgary, Alb.	3,540												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.37	30.00	−.03	22.0	+6.6	30.6	13.4	57	−10	0.98	+0.15	9.
Battleford, Sask.	1,592	28.21	30.02	.00	19.9	+3.6	29.9	10.0	62	−20	0.67	+0.09	6.
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.78	30.04	+.05	42.5	−0.7	46.5	38.6	56	30	5.28	−1.69	0.
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	30.04	30.20	+.15	69.2	+0.5	74.0	64.5	81	61	6.46	+2.08	0.
LATE REPORTS, 1931, VARIOUS MONTHS													
Cape Race, N. F. (June)	99				43.2		47.4	39.0	60	26	4.45		0.
Cape Race, (October)					45.9		52.1	39.7	59	25	2.95		0.
Father Point, Que. (May)	20	29.85	29.87	−0.06	46.0	+2.0	52.7	39.3	64	26	2.01	−0.57	0.
Father Point, Que. (June)		29.90	29.92	+.05	54.3	+1.3	62.8	45.7	74	40	3.29	+0.31	0.
Father Point, Que. (October)													
Winnipeg, Man. (October)	760	29.09	29.92	−.06					84	29	2.07	+0.37	0.
Medicine Hat, Alb. (July)	2,365	27.46	29.90	.00	67.3	−0.5	81.8	52.8	104	40	0.86	−1.23	0.
Medicine Hat, Alb. (October)		27.45	29.94	−.03	46.0	+1.2	60.7	31.3	31	14	0.15	−0.43	0.
Calgary, Alb. (February)	3,428	26.30	30 06	+.07	32.5	+19.0	44.8	20.2	55	7	0.15	−0.48	1.
Calgary, Alb. (March)		26 41	30 23	+.28	26.2	0.0	36.9	15.6	63	−10	2.60	+1.88	26.
Calgary, Alb. (July)		26.34	29.95	+.05	61.7	+1.1	74.0	49.4	91	40	1.60	−1.08	0.
Calgary, Alb. (October)		26.22	29.90	−.05	43.7	+3.6	56.8	30.5	76	16	0.23	−0.25	T.
Banff, Alb. (July)	4,521	25.41	29.92	+.02	58.3	+1.7	74.0	42.5	89	34	1.25	−2.09	0.
Battleford, Sask. (April)	1,592	28.22	29.98	+.01	41.5	+4.3	56.4	26.7	78	15	0.25	−0.22	0.
Edmonton, Alb. (October)	2,150	27.56	29.85	−.08	42.5	+1.4	55.5	29.5	71	16	1 00	+0.30	T.
Kamloops, B. C. (January)	1,262	28.66	29.98	+.02	34.6	+11.6	38.7	30.5	52	20	0.26	−0.56	2.
Kamloops, B. C. (March)		28.72	30.03	+.11	41.6	+5.5	49.1	34.2	63	18	0.80	+0.23	3.
Kamloops, B. C. (May)		28.68	29.96	+.07	59.6	+0.5	70.6	48.6	85	39	0.60	−0.64	T.
Kamloops, B. C. (July)		28.65	29.91	−.03	70.5	+2.0	83.9	57.1	100	47	0.45	−1.16	0.
Estevan Point, B. C. (March)	20				42.9		49.4	36.4	53	29	11.29		0.
Estevan Point, B. C. (May)					50.6		56.3	44.9	64	40	2.87		0.
Estevan Point, B. C. (July)					56.6		63.4	49.8	70	44	0.91		0.
Prince Rupert, B. C. (March)	170				40.5		46.4	34.7	55	22	6.80		T.
Prince Rupert, B. C. (May)					48.6		55.0	42.1	71	32	8.42		0.
Prince Rupert, B. C. (July)					56.0		62.5	49.4	71	42	2.87		0.
Prince Rupert, B. C. (October)					47.5		53.0	42.1	60	35	13.41		0

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ON THE WATER VAPOR IN THE ATMOSPHERE OVER THE UNITED STATES EAST OF THE ROCKY MOUNTAINS

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CONTENTS

INTRODUCTION

I. PURPOSE OF INVESTIGATION

The purpose of this investigation is threefold:

1. To provide a practical method of computing the total mass of water vapor in the lower strata, i. e., to 3 or 4 kilometers, of the atmosphere based upon certain surface observations.

2. To deduce empirical equations based upon the mean values of available data for the lower strata for purposes of extrapolation to obtain tentative approximations of the mass of water vapor in the higher layers of the troposphere.

3. To ascertain and study the average distribution of water vapor in the lower strata of the atmosphere over the United States east of the Rocky Mountains.

II. THEORY OF METHOD

1. *General theory.*—From the gas laws, the mass of water vapor contained in a cubic meter of space is given by

$$1.060\,\frac{e_{mm.}}{1+\alpha t}=0.79507\,\frac{e_{mb.}}{1+\alpha t}=\text{absolute humidity, grams/cu. m.}$$

where e = vapor pressure in units indicated (mm. of mercury, or mb.).

t = temperature in °C.

α = thermal coefficient of cubical expansion, 0.00367.

If e_s = vapor pressure at the surface station, we may write for the absolute humidity at any height, h,

$$(1)\qquad W_h=Ke_s\,\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}\ \text{grams per cubic meter}$$

or

$$(1')\qquad W_h=Ke_s f_h\ \text{grams per cubic meter}$$

where we define $f_h=\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}$, and where K has the value 1.060 when e_s is expressed in millimeters of mercury, and the value 0.79507 when e_s is expressed in millibars. The subscript h refers to the height at which the data are determined. The mass of water vapor in a layer of infinitesimal thickness dh and unit area is

$$(2)\qquad dS=W_h\,dh\ \text{grams},$$

whence S_a^b, the total mass of water vapor contained in a column of air 1 square meter in cross section and extending from $h=a$ to $h=b$ in meters above sea level, is

$$(3)\qquad S_a^b=\int_{h=a}^{h=b}W_h\,dh$$

Substituting equation 1 in equation 3 we get,

$$(4)\qquad S_a^b=K\,e_s\int_{h=a}^{h=b}\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}\,dh$$

or

$$(4')\qquad S_a^b=K\,e_s\,F_a^b\ \text{grams},$$

where by analogy we define $F_a^b=\int_a^b\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}\,dh,$

the sub and super scripts referring to limits of integration.

From the empirical studies of Hann (1), Süring (2) and others, it has been shown that for average conditions the ratio $\left(\frac{e_h}{e_s}\right)$ is nearly constant for each height for widely differing geographical locations, and that it is independent of the value e_s. Hence we may express this value as a function of height,

$$(5)\qquad \left(\frac{e_h}{e_s}\right)=\theta(h).$$

Likewise with suitable restrictions upon place and time, for average conditions, we may express t_h as a function of height,

$$(6)\qquad t_h=\psi(h).$$

Hence it follows that with the proper restrictions, for average conditions, we find S to be a function of height, thus

$$(7)\qquad S_a^b=K\,e_s\int_a^b\frac{\theta(h)}{1+\alpha\psi(h)}dh.$$

It is clear that to determine the mass of water vapor in the given column of air of unit cross-section, we may

either compute the value of the integral by numerical integration of equation *4*, making use of empirical data, or we may obtain the functions $\theta(h)$ and $\psi(h)$ and integrate formally as indicated in equation 7.

2. *Application to the lower strata.*—From what has been stated above, in the case of numerical integration of equation *4* where empirical data are available, for a given place and season we should find the value of the integral F_a^b to be a constant for a given height of column $(b-a)$, under average conditions.

The evaluation of a sufficient number of such integrals for various places and seasons thus affords a simple means of computing the value S_a^b, provided that simple corrections to the values of the integrals may be found for places at heights above sea level different from those of the base stations, and provided also that geographic interpolations of the integrals are permissible. Under these circumstances the value e_s is determined currently and the value S_a^b thus computed is an approximation to the mass of water vapor in the given column of air. The actual value of this variable differs from the computed value depending upon the deviation of the current value of the integral F_a^b from its average value. Other factors which may introduce errors will be discussed in a later section (V).

The practicability of employing the alternative method of finding the value of the integral (i. e., determining the required functional relationships) depends to a great extent upon the complexity of the relationships and their variability with time and place. As may be seen from the data presented in the following section, the actual relationships differ in many small details both with respect to geographic location and to season. For practical purposes it is not essential to be able to reproduce the empirical values

$$f_h=\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}$$

by means of an analytical function, if we have available empirical curves of this function plotted against height, or values of the areas under these curves for suitable limits. Therefore it has been decided to employ this method to determine the values of the integrals for the lower strata of the atmosphere where considerable observational data are available.

3. *Application to the higher strata.*—Thus far, at least three empirical equations have been deduced, giving the average value of the ratio $\left(\frac{e_h}{e_s}\right)$ as a function of height. The well-known equation of Hann (loc. cit.) based largely upon observations made at mountain stations gives

$$\left(\frac{e_h}{e_o}\right)=10^{-\frac{h}{6300}}, \tag{8}$$

where h is the height in meters above sea level at which e_h is the vapor pressure, and e_o is the vapor pressure at sea level.

The equation deduced by Süring (loc. cit.) for the free air is

$$\left(\frac{e_h}{e_o}\right)=10^{-\left(\frac{h}{6}+\frac{h^2}{120}\right)}, \tag{9}$$

where h is here expressed in kilometers.

Süring in the work previously mentioned, on testing the applicability of Hann's equation for values in the free air found that the use of one constant such as 6,500 gave values which were too great above 1 kilometer. However, by dividing up the height into several layers and using an appropriate constant for each layer, the data might be represented fairly closely by this equation. Thus it is stated in the Lehrbuch der Meteorologie of Hann and Süring (fourth edition, p. 244), that "For heights as high as 4.5 km., balloon observations show the constant to be 5,250 m. with good agreement; from 4.5 to 8 km. the constant is 3,550 m. on the average. (4,150 m. is found as the general average)."

On the basis of one year's observations at the Preussischen Aeronautischen Observatorium at Lindenberg, Hergesell (3) has found e_h as a function of temperature and therefrom, e_h as a function of height. He finds

$$\left(\frac{e_h}{e_s}\right)=10^{10.231\left(\frac{t_h}{T_h}-\frac{t_s}{T_s}\right)} \tag{10}$$

where

t_h = temp. in °C. at height h.
t_s = temp. in °C. at the surface of the earth.
T_h = absolute temp. $(273+t)$ °K. at height h.
T_s = absolute temp. $(273+t)$ °K at surface.

Expressing $\left(\frac{t}{T}\right)$ as a function of height he finds for Lindenberg.

$$e_h=7.046\times10^{-\left(\frac{h}{8}+\frac{h^2}{48}\right)} \text{ mm. of mercury,} \tag{11}$$

where h = height above sea level in kilometers. Equation 10 showed good agreement with the means of observations at Batavia, except for values near the height 1.75 km. It was noted in this work that the data would have been fit more closely by the use of a third-order polynomial instead of one of the second order as shown.

Since the value $(1+\alpha t_h)$ does not differ very greatly from unity for temperatures in the troposphere, it is to be expected from the foregoing that only a first approximation to the function $f_h=\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}$ is to be obtained by the use of an exponential function of the type given by Hann, and that closer approximation is obtained by the use of a higher polynomial in the expression. In this connection is may be noted that the evidence at hand shows quite conclusively that in general a Hann type equation gives values which are much too high at heights above 5 km. Thus in one set of data tried, such an equation gave values of the function at 10 km. equivalent to 200 per cent relative humidity.

Data based on a number of sounding balloon flights made in the United States showed for the interval 4–7 km. that the average variation of the function f_h with height could be represented fairly well by means of a second-order exponential function. A greater interval was not used since the hair hygrometer readings for greater heights were increasingly doubtful due to lag in the hygrometer elements (4).

Extrapolation of the function f_h in question by means of a second-order exponential expression is found to give reasonable values for high levels in the great majority of cases. The integration of the resulting function provides a means of obtaining the approximate mass of water

vapor in the higher strata for which relatively few or no reliable observations are available.

III. THE EMPIRICAL DATA

The data used were obtained from the mean seasonal values of free-air vapor pressures and temperatures, for the stations shown in Table 1. In general, one observation was attempted each day.

Table 1.—*Sources of observations*

Station	Altitude, m. s. l.	Latitude N.		Longitude W.		Period of observations (inclusive)				Length of record	
						From—		To—			
	m.	°	′	°	′					*Yrs.*	*Mos.*
Broken Arrow, Okla.	233	36	02	95	49	August,	1918	February,	1929	10	7
Drexel, Nebr.	396	41	20	96	16	November,	1915	March,	1926	10	5
Due West, S. C.	217	34	21	82	22	March,	1921	February,	1929	8	0
Ellendale, N. Dak.	444	45	59	98	34	January,	1918	February,	1929	11	2
Groesbeck, Tex.	141	31	30	96	28	October,	1918	February,	1929	10	5
Leesburg, Ga.	85	31	47	84	14	March,	1919	June,	1920	1	4
Naval Air Station, Washington, D. C.	7	38	54	77	03	July,	1925	February,	1929	3	8
Royal Center, Ind.	225	40	53	86	29	July,	1918	February,	1929	10	8

All of these stations with the exception of the naval air station at Washington, D. C., made the observations by means of kites and captive balloons. The latter station employed airplanes. Observations at the kite stations were usually begun between 7 and 8 a. m., local standard time, and generally lasted from 2 to 3½ hours. More or less variation in the time of beginning an observation was practised. In some cases launching of kites occurred before 7 a. m., and in others as late as 10 a. m. A small proportion of the flights were made during the afternoon. Airplane observations at Washington, D. C., during the period covered by the data showed no great regularity with regard to time of beginning. The flights in this case usually were started between 8 and 9 a. m., and lasted from 15 to 30 minutes. The data may thus be considered as representative of early to midmorning conditions.

The values of the function

$$\left\{\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}\right\}$$

given in Table 2 were computed from corresponding seasonal means of vapor pressure and temperature, respectively. The seasonal means were computed from monthly means, each month's means being given equal weight. Each season was considered to be of three months duration, as follows:

Spring {March. April. May.} Autumn {September. October. November.}

Summer {June. July. August.} Winter {December. January. February.}

The method of differences was used in computing all means, i. e., the arithmetic mean of the surface values is first obtained, then the mean differences from level to level of daily or monthly observed values are computed and finally added successively to the surface mean to give the means for the various levels.

Table 2, which follows, also indicates the total number of daily observations upon which the computed values of the function are based. The seasonal mean *surface* vapor pressures and temperatures are tabulated in the first two columns.

Table 2.—*Seasonal values of the function* $f_h=\left\{\frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}\right\}$

BROKEN ARROW, OKLA. (Surface altitude 233 m., m. s. l.)

Season	Surface: Mean vapor pressure	Surface: Mean temperature	Designation (1)	Altitude above sea level, meters: Surface	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
	Mb.	°*C.*																			
Spring	12.09	15.0	*a*	0.9478	0.9395	0.8339	0.7518	0.6877	0.6181	0.5498	0.4332	0.3437	0.2783	0.2296	0.1841	0.1479	*0.1300	0.1085	-------	-------	-------
			b	778	778	778	774	768	740	695	586	455	330	192	90	40	14	6	-------	-------	-------
Summer	23.21	26.1	*a*	0.9126	0.9050	0.8099	0.7324	0.6686	0.6077	0.5488	0.4421	0.3502	0.2808	0.2251	0.1786	0.1401	0.1121	*0.1082	0.1029	0.1002	-------
			b	686	686	686	684	676	639	597	501	405	279	161	70	33	8	3	2	1	-------
Autumn	13.60	16.6	*a*	0.9426	0.9360	0.8456	0.7689	0.7069	0.6445	0.5781	0.4476	0.3434	0.2664	0.2106	0.1536	0.1186	*0.0987	0.0910	-------	-------	-------
			b	762	762	762	760	744	725	662	560	454	315	192	91	37	8	2	-------	-------	-------
Winter	6.06	4.1	*a*	0.9852	0.9772	0.8738	0.7853	0.7105	0.6374	0.5729	0.4623	0.3848	0.3247	0.2771	0.2357	0.1934	0.1641	0.1392	*0.0962	-------	-------
			b	775	773	772	766	749	706	644	530	411	276	156	91	39	14	6	1	-------	-------

DREXEL, NEBR. (Surface altitude 396 m., m. s. l.)

Season	Mean vapor pressure	Mean temperature	Designation (1)	Surface	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
Spring	8.22	9.3	*a*	0.9670	-------	0.9190	0.8183	0.7439	0.6747	0.6099	0.4976	0.4120	0.3424	0.2802	0.2279	0.1873	0.1444	*0.1069	0.0819	0.0642	-------
			b	903	-------	903	901	876	845	801	693	547	415	242	110	42	20	10	6	2	-------
Summer	18.87	22.9	*a*	0.9225	-------	0.8724	0.7712	0.7023	0.6414	0.5807	0.4748	0.3848	0.3110	0.2506	0.1992	0.1653	0.1347	*0.1218	0.1134	-------	-------
			b	811	-------	811	807	778	752	716	605	498	380	246	122	42	15	6	4	-------	-------
Autumn	9.52	11.1	*a*	0.9609	-------	0.9211	0.8333	0.7639	0.6995	0.6396	0.5336	0.4443	0.3660	0.2977	0.2473	0.2054	0.1662	0.1349	*0.1025	0.0867	-------
			b	867	-------	867	863	849	828	793	700	589	473	330	171	72	24	13	5	2	-------
Winter	3.66	−4.6	*a*	1.0172	-------	0.9702	0.8885	0.8389	0.7959	0.7463	0.6417	0.5461	0.4609	0.3769	0.3002	0.2448	0.2067	*0.1826	-------	-------	-------
			b	939	-------	938	925	909	880	846	760	656	494	278	115	34	14	4	-------	-------	-------

TABLE 2.—*Seasonal values of the function* $f_h=\left\{\dfrac{\left(\dfrac{e_h}{e_s}\right)}{1+\alpha t_h}\right\}$—Continued

Season	Surface: Mean vapor pressure	Surface: Mean temperature	Designation[1]	Surface	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
	Mb.	°C.		Altitude above sea level, meters																	
DUE WEST, S. C. (Surface altitude 217 m., m. s. l.)																					
Spring	12.13	16.4	a	0.9432	0.9286	0.8312	0.7591	0.7000	0.6422	0.5798	0.4561	0.3493	0.2655	0.2042	0.1636	0.1341	*0.1169	------	------	------	------
			b	524	524	524	512	481	438	403	334	253	166	104	51	16	9	------	------	------	------
Summer	22.30	26.3	a	0.9120	0.8997	0.8119	0.7464	0.6907	0.6353	0.5780	0.4731	0.3863	0.3135	0.2592	0.2102	0.1788	*0.1122	0.0632	------	------	------
			b	387	387	386	371	332	292	251	199	163	116	69	32	19	3	1	------	------	------
Autumn	13.81	17.0	a	0.9413	0.9272	0.8402	0.7721	0.7174	0.6570	0.5969	0.4735	0.3769	0.3109	0.2621	0.2232	0.2021	*0.1773	0.1670	------	------	------
			b	465	465	465	452	408	372	327	266	203	131	75	33	15	6	2	------	------	------
Winter	7.74	7.3	a	0.9739	0.9617	0.8763	0.8196	0.7644	0.7041	0.6390	0.5189	0.4080	0.3229	0.2561	0.2112	*0.1625	0.1386	------	------	------	------
			b	523	523	521	510	482	439	401	336	248	158	69	30	10	4	------	------	------	------
ELLENDALE, N. DAK. (Surface altitude 444 m., m. s. l.)																					
Spring	6.29	5.6	a	0.9798	------	0.9545	0.8446	0.7675	0.7039	0.6434	0.5308	0.4311	0.3443	0.2738	0.2135	0.1635	0.1279	*0.0952	0.0789	0.0655	0.0537
			b	949	------	948	945	931	901	851	730	580	415	252	130	56	20	6	3	2	1
Summer	15.85	20.0	a	0.9316	------	0.9049	0.7979	0.7216	0.6549	0.5903	0.4799	0.3957	0.3209	0.2631	0.2174	0.1802	0.1524	*0.1423	0.1326	------	------
			b	910	------	910	910	900	861	811	680	548	403	266	148	64	13	4	2	------	------
Autumn	7.51	6.4	a	0.9770	------	0.9579	0.8749	0.7995	0.7254	0.6578	0.5466	0.4571	0.3810	0.3101	0.2529	0.2043	0.1544	0.1224	0.1001	*0.0691	0.0640
			b	928	------	928	925	917	890	847	738	590	444	294	152	59	26	17	4	2	1
Winter	2.56	−10.1	a	1.0385	------	1.0178	0.9581	0.9219	0.8876	0.8354	0.7145	0.5984	0.4769	0.3656	0.2897	0.2461	0.1890	0.1435	*0.1354	------	------
			b	949	------	947	945	929	888	843	728	584	395	216	95	32	9	5	1	------	------
GROESBECK, TEX. (Surface altitude 141 m., m. s. l.)																					
Spring	15.43	17.9	a	0.9381	0.9010	0.8144	0.7375	0.6545	0.5683	0.4842	0.3589	0.2833	0.2328	0.1922	0.1619	0.1380	*0.1341	0.1206	------	------	------
			b	833	832	830	816	785	743	693	581	442	282	138	68	26	14	4	------	------	------
Summer	25.19	26.4	a	0.9117	0.8836	0.8082	0.7136	0.6206	0.5507	0.4923	0.3967	0.3238	0.2662	0.2191	0.1807	0.1463	*0.1311	------	------	------	------
			b	755	755	753	728	695	652	598	451	318	176	84	38	12	6	------	------	------	------
Autumn	17.21	18.8	a	0.9355	0.9032	0.8261	0.7533	0.6744	0.5989	0.5330	0.4099	0.3160	0.2416	0.1928	0.1503	0.1215	0.1013	0.0767	------	------	------
			b	761	761	756	732	696	643	592	494	396	278	154	84	35	13	4	------	------	------
Winter	9.26	9.0	a	0.9681	0.9290	0.8478	0.7772	0.6953	0.6228	0.5495	0.4300	0.3491	0.2842	0.2304	0.1964	0.1651	0.1424	0.1225	*0.1127	0.1068	0.1031
			b	844	844	840	808	762	708	650	552	426	299	163	79	43	21	6	1	1	1
LEESBURG, GA. (Surface altitude 85 m., m. s. l.)																					
Spring	14.98	20.0	a	0.9316	0.8611	0.7830	0.7214	0.6659	0.6100	0.5494	0.4066	0.3479	0.2820	*0.2549	0.2337	0.2200	------	------	------	------	------
			b	88	88	84	77	65	59	49	32	25	20	10	4	3	------	------	------	------	------
Summer	24.86	28.6	a	0.9050	0.8451	0.7830	0.7418	0.6855	0.6207	0.5526	0.4472	0.3677	0.3274	0.2848	*0.2598	------	------	------	------	------	------
			b	51	51	51	45	37	29	27	24	19	15	7	3	------	------	------	------	------	------
Autumn	18.40	23.5	a	0.9206	0.8702	0.8077	0.7453	0.6780	0.6177	0.5468	0.4065	0.2982	0.2282	0.1791	*0.1591	0.1298	------	------	------	------	------
			b	48	48	47	43	36	32	29	22	18	14	9	6	3	------	------	------	------	------
Winter	10.00	12.7	a	0.9555	0.8920	0.8102	0.7508	0.6856	0.6223	0.5612	0.4319	0.3541	0.2922	*0.2112	0.1545	0.1440	------	------	------	------	------
			b	67	67	66	60	56	53	48	44	37	25	10	4	2	------	------	------	------	------
NAVAL AIR STATION, WASHINGTON, D. C. (surface altitude 7 m., m. s. l.)																					
Spring	9.77	12.1	a	0.9575	0.8680	0.7752	0.6943	0.6376	0.5902	0.5495	0.4550	0.3632	0.2847	0.2322	0.1746	*0.1210	0.0790	0.0502	0.0286	------	------
			b	175	176	175	174	171	168	162	146	120	89	61	45	7	2	1	1	------	------
Summer	21.70	24.2	a	0.9184	0.8382	0.7491	0.6758	0.6143	0.5615	0.5195	0.4370	0.3448	0.2616	0.2001	0.1463	*0.0705	0.0374	0.0114	------	------	------
			b	175	175	175	171	169	165	161	144	127	106	38	30	2	1	1	------	------	------
Autumn	13.49	14.6	a	0.9191	0.8659	0.7909	0.7259	0.6738	0.6230	0.5706	0.4599	0.3553	0.2636	0.1936	*0.1325	0.0849	0.0420	------	------	------	------
			b	185	185	183	183	181	175	169	151	129	91	35	17	1	1	------	------	------	------
Winter	4.87	1.3	a	0.9953	0.9260	0.8523	0.7968	0.7393	0.6853	0.6327	0.5390	0.4545	0.3655	0.2944	*0.2459	0.2155	------	------	------	------	------
			b	149	149	146	146	144	142	139	121	103	60	19	12	2	------	------	------	------	------
ROYAL CENTER, IND. (surface altitude 225 m., m. s. l.)																					
Spring	8.84	10.2	a	0.9639	0.9492	0.8269	0.7437	0.6754	0.6111	0.5541	0.4536	0.3520	0.2775	0.2236	0.1814	0.1537	*0.1364	0.1273	0.1120	------	------
			b	704	704	704	693	665	633	597	486	359	242	136	73	39	18	7	1	------	------
Summer	18.69	23.4	a	0.9209	0.9090	0.8071	0.7415	0.6862	0.6271	0.5631	0.4382	0.3258	0.2479	0.1875	0.1456	*0.1238	0.1101	0.1051	0.0871	------	------
			b	588	584	583	564	529	491	460	388	286	182	104	44	16	4	3	1	------	------
Autumn	11.20	12.7	a	0.9555	0.9450	0.8479	0.7757	0.7043	0.6341	0.5669	0.4485	0.3529	0.2826	0.2265	0.1640	0.1345	*0.1109	0.0858	------	------	------
			b	722	720	719	701	662	618	583	485	392	274	138	54	24	7	2	------	------	------
Winter	4.32	−2.5	a	1.0093	0.9937	0.8834	0.8070	0.7321	0.6595	0.5992	0.4929	0.4200	0.3611	0.3016	0.2505	0.2162	0.1759	------	------	------	------
			b	773	773	773	752	729	680	634	528	370	208	96	31	7	1	------	------	------	------

[1] a = value of function f_h, b = number of observations.

* Values thus indicated and those for higher levels considered relatively doubtful.

Values of the function are computed to four decimal places; however, they are not to be regarded as accurate to that many figures, except possibly where based upon a large number of observations. In general, values based upon fewer than about 25 observations are considered to be in doubt in the second and possibly in the first decimal place. (See Secs. IV and V for discussions of errors.)

IV. COMPUTATION OF CONSTANTS OF THE EQUATIONS

1. Graphical integration of equation (4) for given data.—The function f_h has been plotted against height for the data given in TABLE 2. Some examples of the resulting curves are shown in Figures 1–8, for Ellendale, N. Dak. and Groesbeck, Tex., the most northern and southern stations, respectively, in the given group.

The evaluation of equation 4 was accomplished by drawing smooth curves through the plotted points as shown in the above figures, and reading the mean values of the ordinates f_h for each hundred-meter interval. The value of the definite integral is then obtained when the sum of the resulting mean ordinates is multiplied by 100. This method has advantages over the usual meth

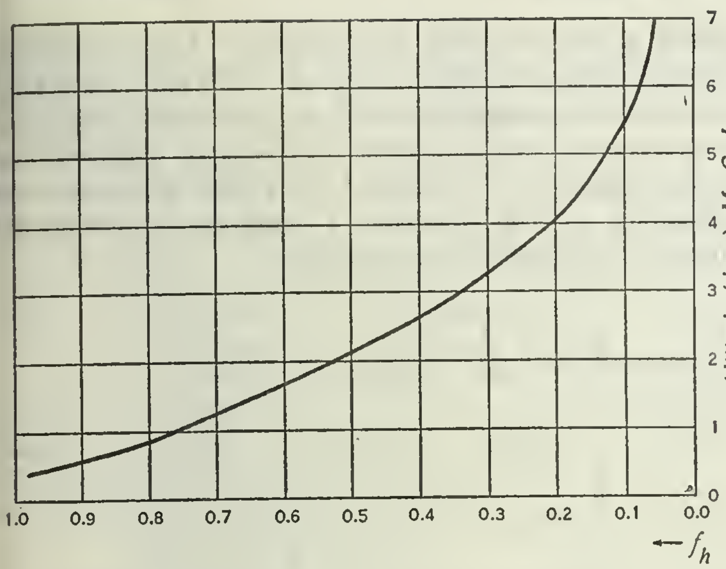


FIGURE 1.—Ellendale, N. Dak. Spring. f_h plotted against height

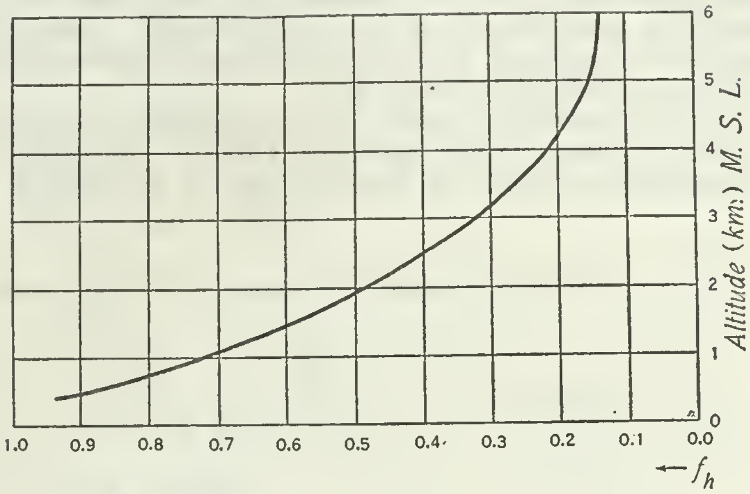


FIGURE 2.—Ellendale, N. Dak. Summer. f_h plotted against height

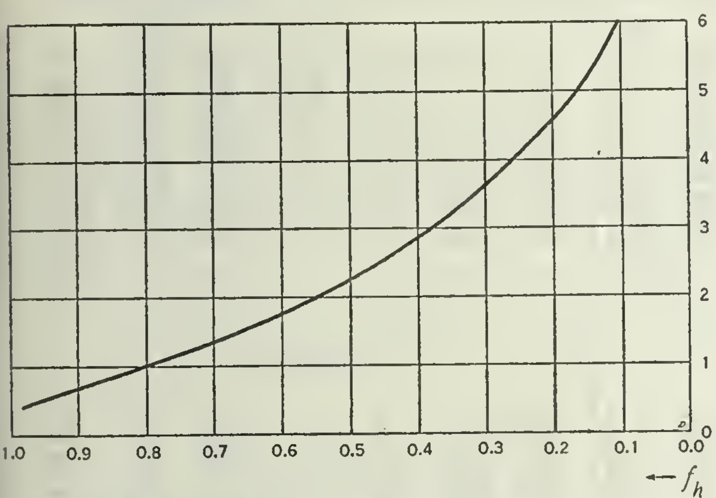


FIGURE 3.—Ellendale, N. Dak. Autumn. f_h plotted against height

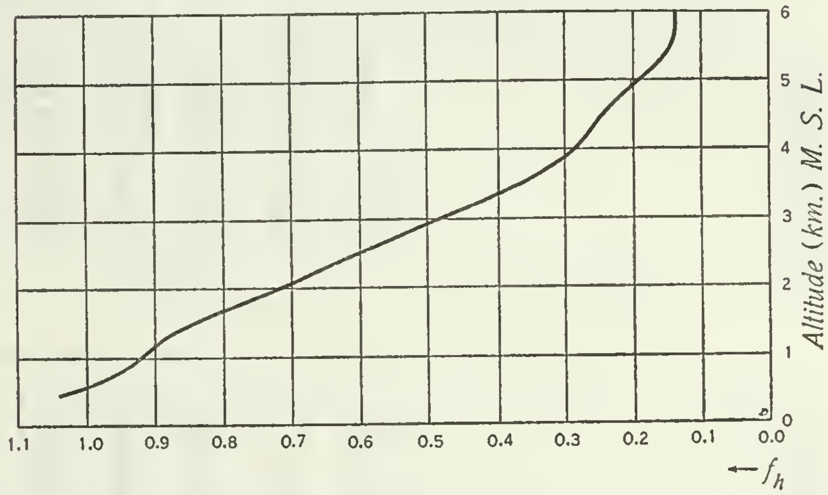


FIGURE 4.—Ellendale, N. Dak. Winter. f_h plotted against height

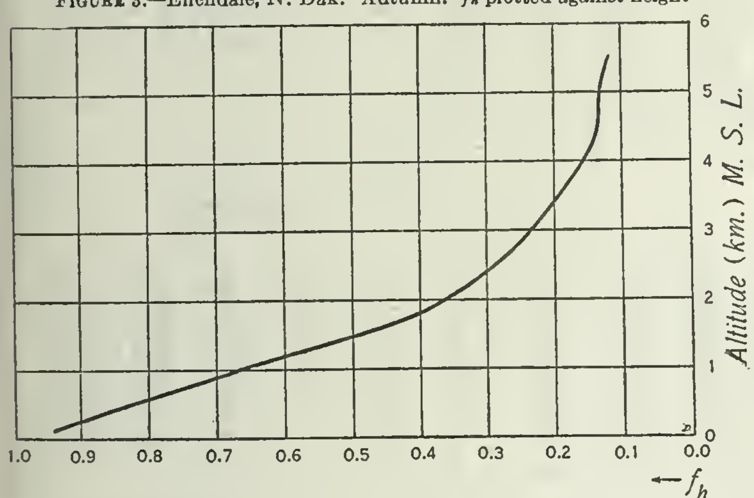


FIGURE 5.—Groesbeck, Tex. Spring. f_h plotted against height

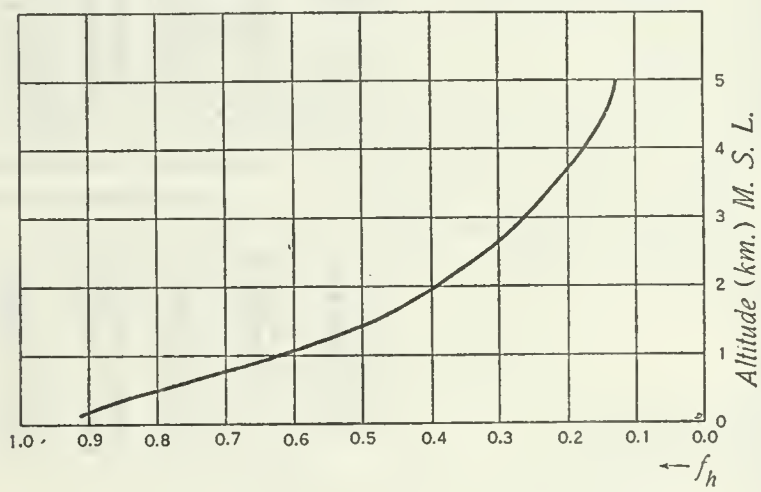


FIGURE 6.—Groesbeck, Tex. Summer. f_h plotted against height

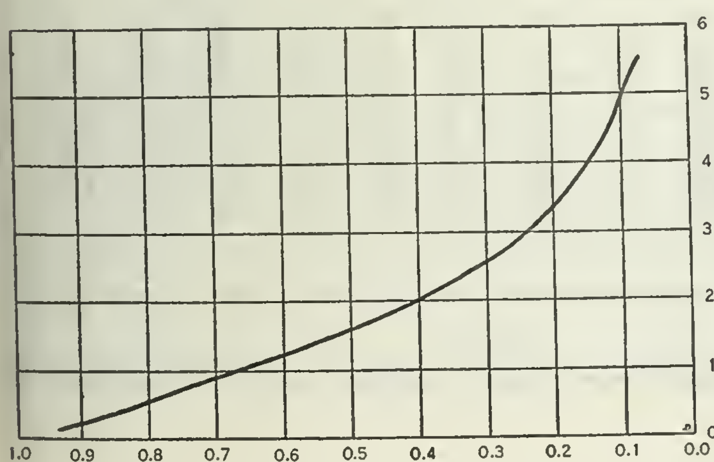


FIGURE 7.—Groesbeck, Tex. Autumn. f_h plotted against height

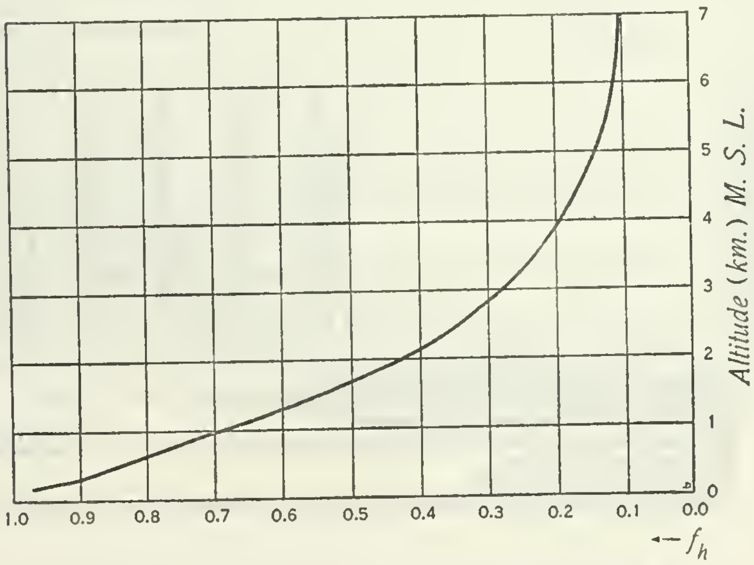


FIGURE 8.—Groesbeck, Tex. Winter. f_h plotted against height

ods of numerical integation such as Simpson's rules, since the curves could not be represented over their entire length by polynomials of any given degree. Adequate accuracy is attained by taking sufficiently narrow strips such as are indicated above (**5**).

Table 3 shows the results of the graphical integration of the functional values given in Table 2, and also, the corresponding values of the function S as defined in equation 4 for seasonal mean surface vapor pressures, where the surface heights above sea level are taken as the lower limits of integration and the indicated heights (h) are taken as the upper limits. We may thus compare both the values of F_s^h (defined in Table 3), which were required for use in equation 4, and the corresponding values of $\bar{S}_s^h$ for average conditions.

TABLE 3.—*Values of the integrals*[1]: $F_s^h=\int_s^h f_h dh=\int_s^h \frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h} dh$ *and* $\bar{S}_s^h=K\bar{e}_s\int_s^h \frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h} dh=K\bar{e}_s\cdot F_s^h$ *grams*

BROKEN ARROW, OKLA. (233 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
m.		*Kg.*		*Kg.*		*Kg.*		*Kg.*
500	236	2.27	228	4.21	237	2.56	247	1.19
1,000	615	5.91	595	10.98	622	6.72	641	3.09
1,500	924	8.88	899	16.59	944	10.20	959	4.62
2,000	1,169	11.24	1,144	21.11	1,196	12.93	1,216	5.86
2,500	1,361	13.08	1,341	24.74	1,393	15.06	1,427	6.88
3,000	1,516	14.57	1,498	27.64	1,545	16.70	1,604	7.73
3,500	1,642	15.78	1,624	29.96	1,664	17.99	1,754	8.45
4,000	1,744	16.76	1,726	31.84	1,754	18.96	1,881	9.06
4,500	1,827	17.56	1,805	33.30	1,822	19.70	1,989	9.58
5,000	*1,896	*18.22	1,868	34.46	*1,876	*20.28	2,078	10.01
5,500	1,956	18.80	*1,923	*35.48	1,923	20.79	2,154	10.38
6,000			1,976	36.46			*2,212	*10.66
6,500			2,027	37.40				
7,000								

GROESBECK, TEX. (141 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
m.		*Kg.*		*Kg.*		*Kg.*		*Kg.*
500	314	3.85	309	6.19	316	4.32	324	2.39
1,000	682	8.37	664	13.30	691	9.45	711	5.23
1,500	966	11.85	939	18.81	991	13.56	1,020	7.51
2,000	1,172	14.38	1,159	23.21	1,225	16.76	1,262	9.29
2,500	1,333	16.36	1,338	26.80	1,406	19.23	1,455	10.71
3,000	1,461	17.93	1,485	29.74	1,544	21.12	1,611	11.86
3,500	1,567	19.23	1,605	32.15	1,652	22.60	1,739	12.80
4,000	1,655	20.31	1,704	34.13	1,737	23.76	1,846	13.59
4,500	1,730	21.23	1,785	35.75	1,804	24.68	1,936	14.25
5,000	*1,797	*22.05	*1,854	*37.14	1,860	25.44	2,013	14.82
5,500	1,861	22.83			1,906	26.07	2,079	15.31
6,000							*2,138	*15.74
6,500							2,193	16.14
7,000							2,245	16.53

DREXEL, NEBR. (396 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	97	0.63	93	1.40	97	0.73	102	0.30
1,000	507	3.31	480	7.20	514	3.89	547	1.59
1,500	842	5.50	799	11.98	862	6.52	943	2.74
2,000	1,116	7.29	1,060	15.90	1,151	8.71	1,290	3.75
2,500	1,342	8.77	1,273	19.10	1,393	10.54	1,585	4.61
3,000	1,530	10.00	1,447	21.70	1,593	12.06	1,836	5.34
3,500	1,684	11.00	1,587	23.80	1,756	13.29	2,044	5.95
4,000	1,811	11.83	1,698	25.47	1,890	14.31	2,213	6.44
4,500	1,914	12.51	1,788	26.82	2,002	15.15	2,347	6.83
5,000	1,996	13.04	1,863	27.94	2,095	15.86	2,459	7.16
5,500	*2,057	*13.44	*1,927	*28.90	2,170	16.42	*2,555	*7.44
6,000	2,104	13.75	1,985	29.78	*2,228	*16.86		
6,500	2,140	13.98			2,276	17.23		
7,000								

LEESBURG, GA. (85 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	352	4.19	346	6.84	357	5.22	366	2.91
1,000	713	8.49	715	14.14	728	10.65	740	5.88
1,500	1,017	12.11	1,024	20.24	1,036	15.16	1,050	8.35
2,000	1,254	14.94	1,273	25.17	1,276	18.67	1,300	10.34
2,500	1,439	17.14	1,475	29.16	1,450	21.21	1,494	11.88
3,000	1,597	19.02	1,647	32.56	1,580	23.12	1,655	13.16
3,500	*1,731	*20.62	1,801	35.61	1,681	24.59	*1,782	*14.17
4,000	1,853	22.07	*1,935	*38.25	*1,766	*25.84	1,873	14.89
4,500	1,966	23.42			1,838	26.89	1,947	15.48
5,000								
5,500								
6,000								
6,500								
7,000								

DUE WEST, S. C. (217 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	248	2.39	242	4.29	250	2.74	261	1.61
1,000	628	6.06	614	10.89	636	6.98	669	4.12
1,500	948	9.14	931	16.51	965	10.60	1,018	6.26
2,000	1,205	11.62	1,191	21.12	1,228	13.48	1,306	8.04
2,500	1,405	13.55	1,402	24.86	1,439	15.80	1,537	9.46
3,000	1,557	15.02	1,574	27.91	1,609	17.67	1,719	10.58
3,500	1,674	16.14	1,716	30.42	1,751	19.23	1,863	11.46
4,000	1,766	17.03	1,833	32.50	1,872	20.55	1,979	12.18
4,500	1,839	17.74	1,930	34.22	1,977	21.71	*2,072	*12.75
5,000	*1,901	*18.33	*2,002	*35.50	*2,072	*22.75	2,146	13.21
5,500			2,045	36.26	2,158	23.69		
6,000								
6,500								
7,000								

NAVAL AIR STA., WASHINGTON, D. C. (7 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	426	3.31	412	7.11	426	4.57	456	1.7
1,000	776	6.03	751	12.95	789	8.47	853	3.3
1,500	1,070	8.31	1,034	17.84	1,101	11.81	1,194	4.6
2,000	1,319	10.25	1,270	21.91	1,357	14.56	1,484	5.7
2,500	1,522	11.82	1,465	25.27	1,558	16.72	1,731	6.7
3,000	1,683	13.07	1,616	27.88	1,710	18.35	1,935	7.4
3,500	1,812	14.08	1,732	29.88	1,823	19.56	2,097	8.1
4,000	1,914	14.87	1,817	31.34	*1,903	*20.42	*2,232	*8.6
4,500	*1,988	*15.44	*1,872	*32.29	1,957	21.00	2,346	9.0
5,000	2,037	15.82	1,897	32.72	1,988	21.33		
5,500	2,068	16.06	1,910	32.95				
6,000	2,088	16.22						
6,500								
7,000								

ELLENDALE, N. DAK. (444 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	54	0.27	51	0.64	54	0.32	58	0.12
1,000	478	2.39	453	5.71	494	2.95	539	1.10
1,500	830	4.15	779	9.82	857	5.12	981	2.00
2,000	1,122	5.61	1,044	13.15	1,157	6.91	1,369	2.79
2,500	1,361	6.81	1,262	15.90	1,407	8.40	1,697	3.45
3,000	1,555	7.78	1,440	18.14	1,616	9.65	1,966	4.00
3,500	1,709	8.55	1,585	19.97	1,788	10.68	2,174	4.42
4,000	1,830	9.15	1,704	21.47	1,929	11.52	2,334	4.75
4,500	1,923	9.62	1,804	22.73	2,042	12.19	2,467	5.02
5,000	1,995	9.98	1,887	23.78	2,132	12.73	2,576	5.24
5,500	*2,051	*10.26	*1,961	*24.71	2,202	13.15	2,658	5.41
6,000	2,094	10.47	2,030	25.58	2,257	13.48	*2,727	*5.55
6,500	2,131	10.66			*2,300	*13.73		
7,000	2,160	10.80			2,332	13.92		

ROYAL CENTER, IND. (225 m.)

Upper limit-h	Spring F_s^h	Spring $\bar{S}_s^h$	Summer F_s^h	Summer $\bar{S}_s^h$	Autumn F_s^h	Autumn $\bar{S}_s^h$	Winter F_s^h	Winter $\bar{S}_s^h$
500	242	1.70	235	3.49	245	2.18	258	0.8
1,000	614	4.32	606	9.01	631	5.62	660	2.2
1,500	919	6.46	918	13.64	947	8.43	990	3.4
2,000	1,171	8.23	1,168	17.36	1,199	10.68	1,260	4.3
2,500	1,371	9.64	1,357	20.17	1,398	12.45	1,488	5.1
3,000	1,526	10.72	1,499	22.28	1,556	13.86	1,682	5.7
3,500	1,650	11.60	1,607	23.88	1,683	14.99	1,818	6.3
4,000	1,750	12.30	1,689	25.10	1,782	15.87	1,986	6.8
4,500	1,833	12.88	*1,756	*26.09	1,855	16.52	2,102	7.2
5,000	*1,905	*13.39	1,814	26.96	*1,917	*17.07	2,200	7.5
5,500	1,971	13.85	1,867	27.74	1,966	17.51		
6,000	2,030	14.27	1,916	28.47				
6,500								
7,000								

[1] s = height of surface in meters above sea-level.
h = height of upper limit of column, meters above sea level.
$\bar{e}_s$ = mean seasonal surface vapor pressure.
$\bar{S}_s^h$ = mean (seasonal) mass of water vapor in column of air 1 sq. m. in cross-section and extending from surface to height h, in grams for K given as below (here given in *Kg.*).
K=1.060 when e_s is in mm.
K=0.79507 when e_s is in mb.
*Values thus indicated and those for higher levels considered relatively doubtful.

The values of F^h_s introduced above permit the com- utation of the mass of water vapor in a column of air ·om the ground to various heights above sea level, ·here the surface vapor pressure is known.

2. *Arbitrary selection of levels where values are con- :dered relatively doubtful.*—As is evident from the curves 1own (figs. 1–8), some irregularities exist in the data for 1e upper levels. Whether these irregularities are due to ·wness of observations, instrumental errors, or represent real average condition, it is impossible to say with ertainty. Since some criteria are necessary to decide s to which values are sufficiently in error (relative to 1ore reliable values for lower levels) to be discarded for resent purposes, it was decided to use the following hree indications as decisive in this matter:

(*a*) Number of observations,
(*b*) Smoothness of curves, f_h plotted against height, and
(*c*) Smoothness of curves, log f_h plotted against height.

'he latter criterion is permissible since in general the inction is exponential in nature.

In pursuance of this scheme all of the data were plotted pon semilogarithmic paper and curves drawn through he plotted points. Some examples of the resulting curves re shown in Figures 9 to 18 inclusive. Functions vary- 1g according to an equation similar to Hann's type, quation 8, appear here as straight lines, while those arying according to an equation similar to Süring's ype, equation 9, appear as parabolas. Slight modifica- ions of these two types are to be seen in Figures 9 and 0, respectively.

Finally the various curves were carefully examined nd judged according to the criteria previously proposed. ,evels at and above which the values f_h and F^h_s were con- idered relatively doubtful are indicated in Tables 2 and by means of asterisks.

This procedure is of course rather arbitrary, but it is onsidered more desirable to weight the values in this nanner than to present them as though having equal 'alidity. It is the more important to do this since not ll the curves can be reproduced.

Some of the values thus marked off are quite certainly ess in doubt than others; however, no satisfactory ab- olute standard for comparison is known to exist. Values or Leesburg, Ga., and Washington, D. C., are considered o be much less reliable on the whole than values for the ther stations, largely on account of the relative fewness f observations.

In addition, the effect of lag in the hair hygrometers 1sed in the meteorographs is in general to make the ndicated values too high, where the instrument goes rom warmer to colder air (**4**). At low temperatures below −30° C.) this effect has been found by Klein- chimdt (loc. cit.) to be quite large. The result of such n effect is to displace the logarithmic curves too far to he right. (See figs. 9–18.)

The curves for Washington, D. C., for all seasons, xcept winter, show a marked divergence in trend from he others in the high levels, indicating a rapid decrease f absolute humidity with height. This may be partly lue to the fact that observations at the other stations vere made during all kinds of weather except heavy or noderate rain or snow, whereas relatively fewer were nade at the latter station on days when threatening, noist conditions prevailed at low levels. On the other hand, as has been noted by Gregg (**6**) and later by Wagner (**7**), temperatures in the free air are lower over the Atlantic coast than at corresponding latitudes in the interior of the continent. This is most strongly pro- nounced during the warmer seasons and at Northern stations. Hence we may draw the conclusion that the observed trend in the data for Washington, D. C., is probably indicative of the actual trend existing over that place. It may be noted that the few data available for heights above 4.5 km., for summer at Due West, S. C., indicate the same tendency.

3. *Tentative approximate computation of the constants* ***F*** *for the higher strata.*—A consideration of the factors governing the distribution of water vapor in the tropo- sphere leads to the conclusion that the water vapor con- tent above 4–5 km. should decrease more rapidly in geometric progression than below those heights. This is borne out by the smaller value of the constant found by Hann for the interval 4.5 − 8 km. (See quotation from the Lehrbuch der Meteorologie previously given.) An examination of 91 sounding-balloon flights made in the United States showed that data for the interval 4–7 km. could be represented under average conditions by an equation of the form

$$f_h = f_d 10^{-[c_1(h-d)+c_2(h-d)^2]} \tag{12}$$

where

$$f_h = \text{value of the function } \frac{\left(\frac{e_h}{e_s}\right)}{1+\alpha t_h}$$

at height h, in meters.

f_d = known value of the same function at height d, the latter serving as a datum height, and c_1 and c_2 are constants.

The constant $-c_1$ represents the slope of the semi- logarithmic curve at height d, h being taken as the independent variable.

The constant c_2 was found to have a seasonal and geographical variation. The data at hand did not give entirely consistent values of this constant, as was to be expected. The very approximate results thus obtained were smoothed out. Comparisons were then made to determine whether these results gave reasonable values of humidity at high elevations. Slight modifications were found necessary. The final tentative values are given in the following table:

TABLE 4.—*Tentative values of c_2**

Season	Northern stations	Southern stations
	$m.^{-2}$	$m.^{-2}$
Spring	2.6×10^{-8}	2.5×10^{-8}
Summer	2.0×10^{-8}	1.9×10^{-8}
Autumn	2.4×10^{-8}	2.1×10^{-8}
Winter	3.0×10^{-8}	2.7×10^{-8}

* The dimensions of c_2 are reciprocal square meters as indicated at the column heads

It may be noted that the constant 1/48 in Hergesell's equation (11) is equivalent to the constant 2.1×10^{-8} when h is expressed in meters.

Corresponding values of f_d and c_1 for the eight stations are given in Table 5.

The intervals of height from which the slopes $-c_1$ were obtained are also indicated. In general, the value f_d was chosen on the basis of the reliability criteria previously discussed.

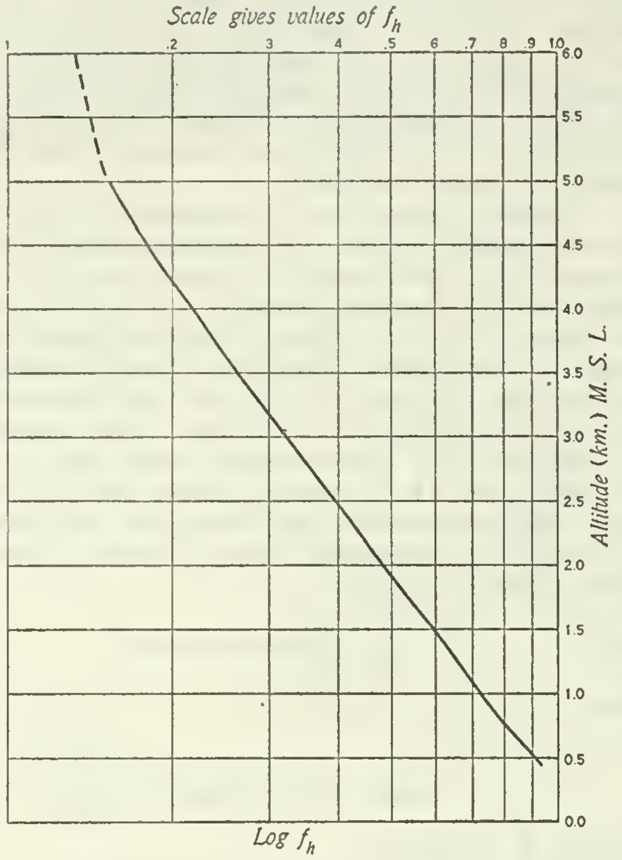


FIGURE 9.—Ellendale, N. Dak. Summer. $\log_{10} f_h$ plotted against height

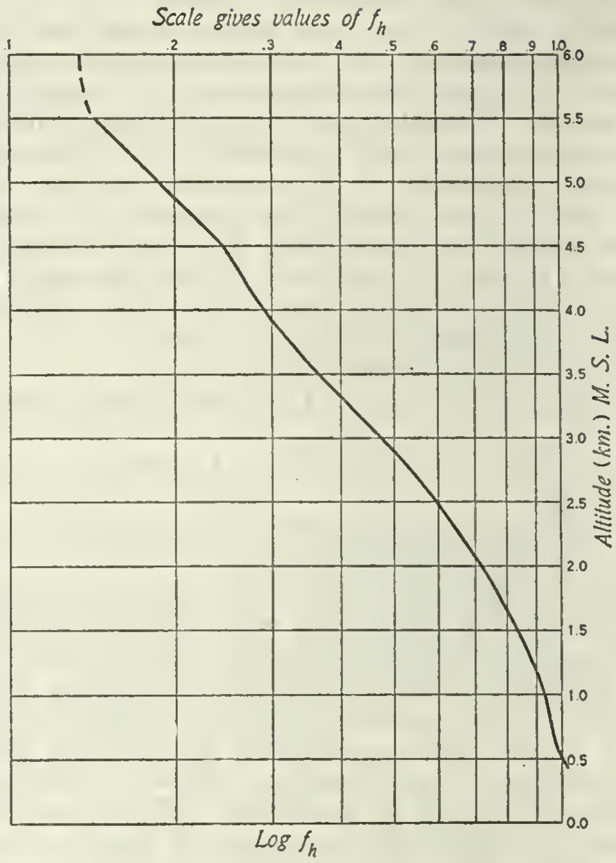


FIGURE 10.—Ellendale, N. Dak. Winter. $\log_{10} f_h$ plotted against height

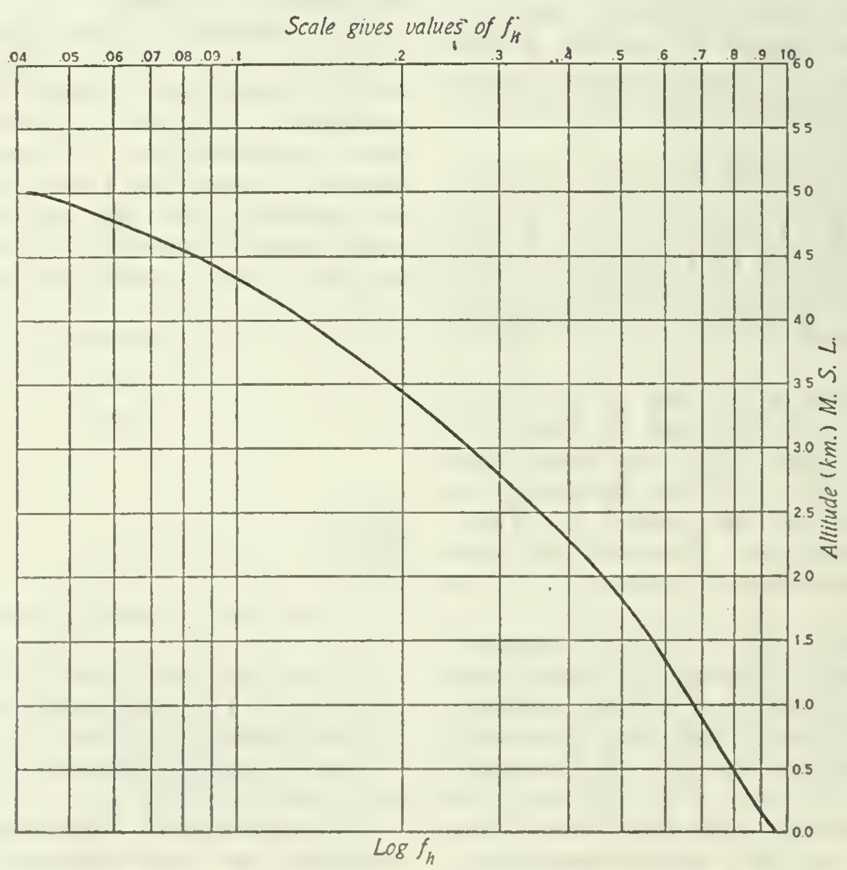


FIGURE 11.—Washington, D. C. Autumn. $\log_{10} f_h$ plotted against height

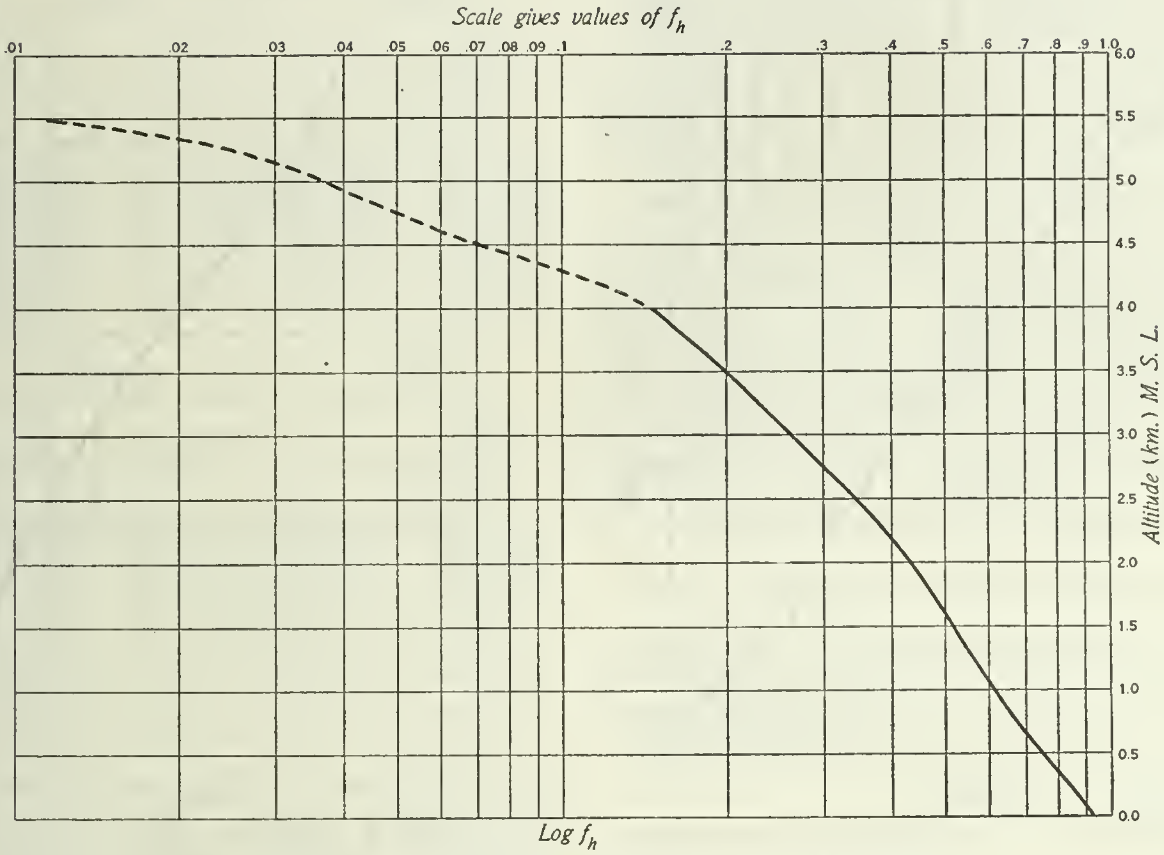


FIGURE 12.—Washington, D. C. Summer. $\log_{10} f_h$ plotted against height

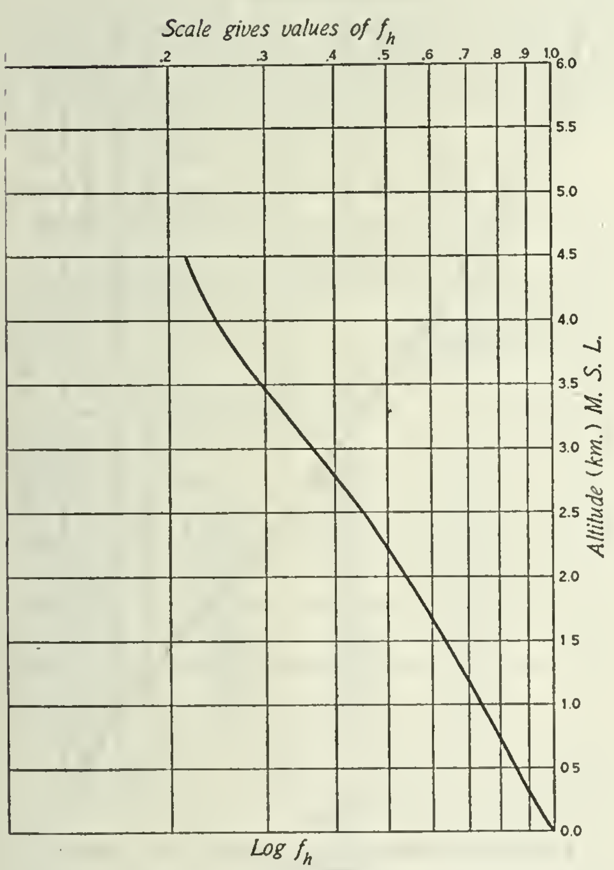


FIGURE 13.—Washington, D. C. Winter. $\log_{10} f_h$ plotted against height

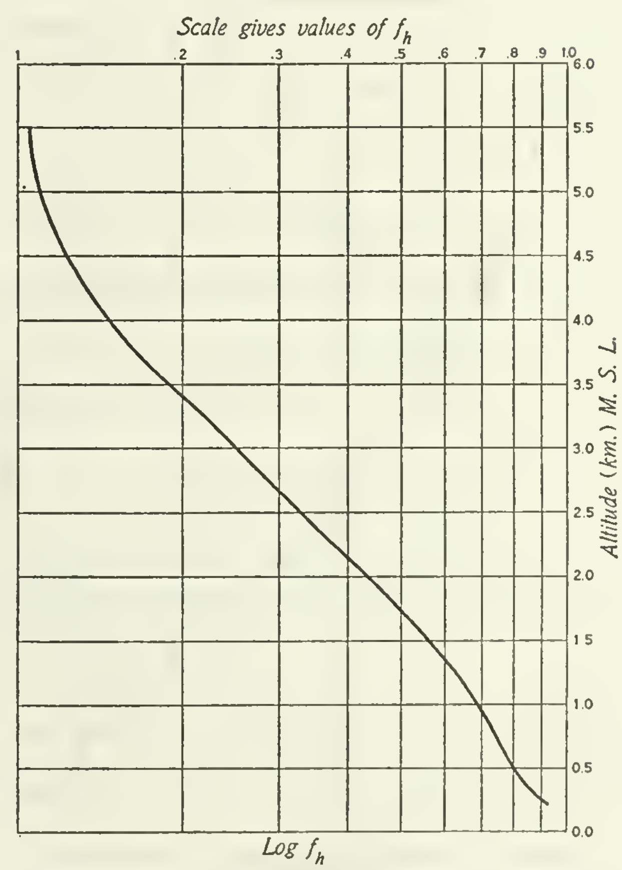


FIGURE 14.—Royal Center, Ind. Summer. $\log_{10} f_h$ plotted against height

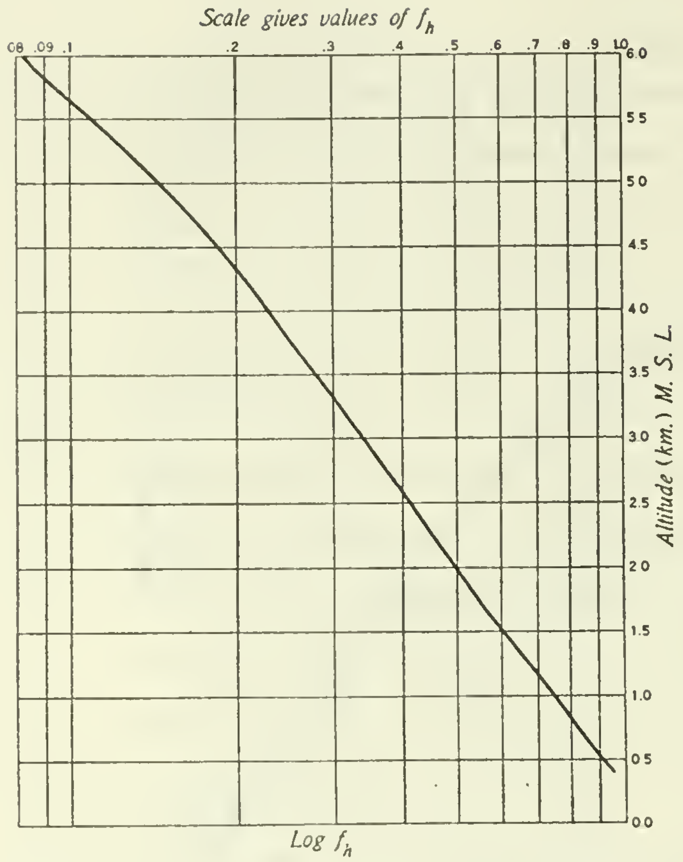


FIGURE 15.—Drexel, Nebr. Spring. $Log_{10} f_h$ plotted against height

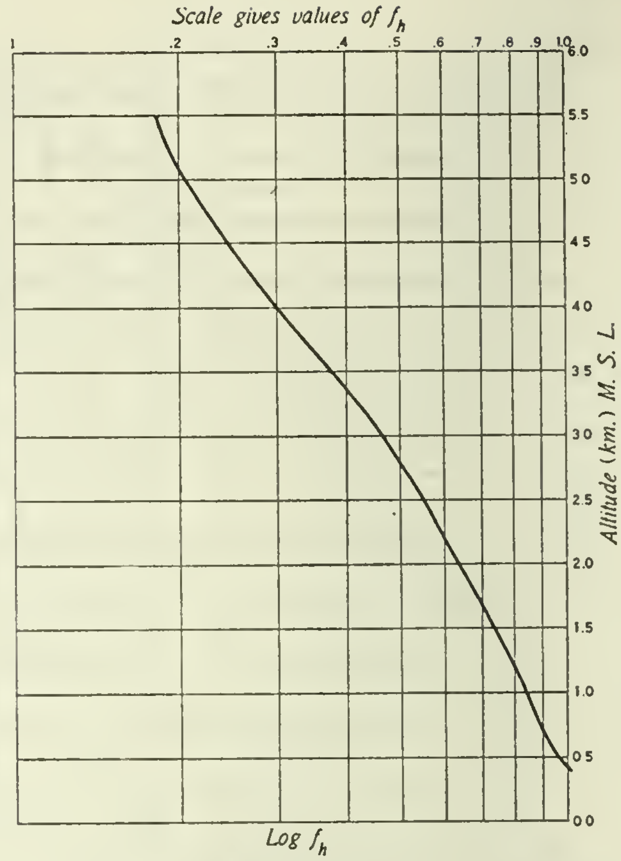


FIGURE 16.—Drexel, Nebr. Winter. $Log_{10} f_h$ plotted against height

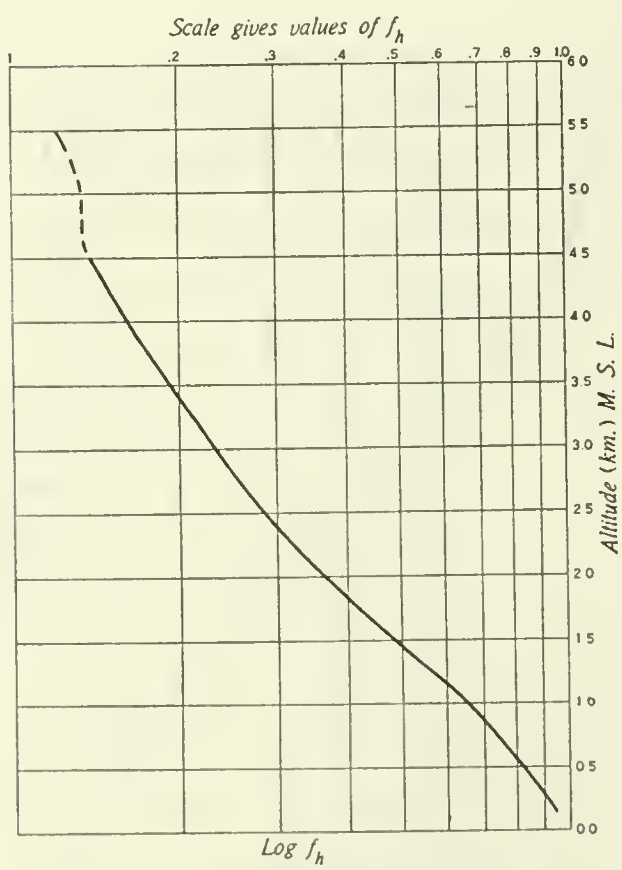


FIGURE 17.—Groesbeck, Tex. Spring. $Log_{10} f_h$ plotted against height

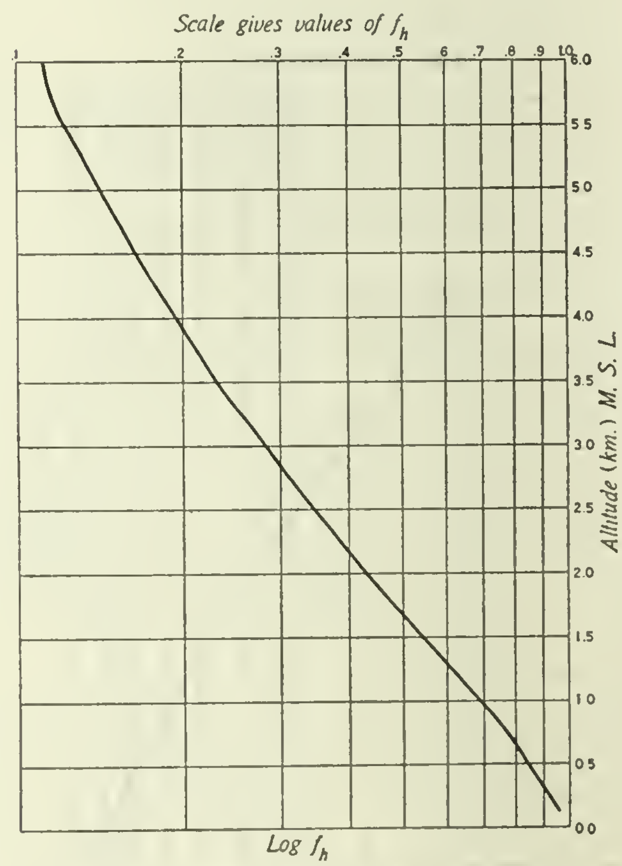


FIGURE 18.—Groesbeck, Tex. Winter. $Log_{10} f_h$ plotted against height

'ABLE 5.—*Data used for extrapolation of f_h to heights greater than for which it is available, according to equation 12*

Station	Spring				Summer			
	d	f_d	c_1	Interval [1]	d	f_d	c_1	Interval [1]
	m.		10^{-4} *m.*$^{-1}$	*Km.*	*m.*		10^{-4} *m.*$^{-1}$	*Km.*
roken Arrow, Okla.	4,500	0.1479	1.90	4.0–4.5	4,500	0.1401	2.11	4.0–4.5
rexel, Nebr.	5,000	.1444	2.26	4.5–5.0	5,000	.1347	1,78	4.5–5.0
ue West, S. C.	4,000	.1636	1.93	3.5–4.0	4,000	.2102	1.82	3.5–4.0
llendale, N. Dak.	5,000	.1279	2.13	4.5–5.0	4,500	.1802	1.63	4.0–4.5
roesbeck, Tex.	4,000	.1619	1.49	3.5–4.0	4,500	.1463	1.75	3.5–4.5
eesburg, Ga.	3,000	.2820	1.82	2.5–3.0	2,500	.3677	1.70	2.0–2.5
aval Air Station, Washington, D. C.	3,500	.2322	2.12	3.0–4.0	3,500	.2001	2.52	3.0–4.0
oyal Center, Ind.	4,000	.1814	1.82	3.5–4.0	4,000	.1456	1.80	3.5–4.5

Station	Autumn				Winter			
	d	f_d	c_1	Interval [1]	d	f_d	c_1	Interval [1]
	m.		10^{-4} *m.*$^{-1}$	*Km.*	*m.*		10^{-4} *m.*$^{-1}$	*Km.*
roken Arrow, Okla.	4,500	0.1186	2.25	4.0–4.5	4,500	0.1934	1.72	4.0–4.5
rexel, Nebr.	6,000	.1025	2.39	5.5–6.0	4,500	.2448	1.77	4.0–4.5
ue West, S. C.	3,500	.2621	1.48	3.0–3.5	4,000	.2112	1.67	3.5–4.0
llendale, N. Dak.	5,000	.1544	2.22	4.5–5.0	5,500	.1435	2.34	4.5–5.5
roesbeck, Tex.	4,500	.1215	1.85	4.0–5.0	4,500	.1651	1.51	4.0–4.5
eesburg, Ga.	3,500	.1791	1.57	3.0–4.0	3,000	.2922	1.67	2.5–3.0
aval Air Station, Washington, D. C.	3,000	.2636	2.59	2.5–3.0	3,500	.2944	1.88	3.0–3.5
oyal Center, Ind.	4,500	.1345	1.72	4.0–4.5	4,000	.2505	1.61	3.5–4.0

[1] Columns thus headed indicate interval of data from which value c_1 was obtained.

Examples of results of computation by means of equa-
ion 12 are shown in Table 6 for autumn at Groesbeck, 'ex. Mean temperatures were obtained by applying he mean lapse rates obtained from the sounding-balloon eries of October, 1927, made at that station (**8**) to the iean temperature at 4 km., which had been obtained ·om kite records for the season in question. Vapor ressures were computed by using the temperatures ›und as described above to give $e_h=f_h[\bar{e}_s(1+at_h)]$. Relative humidities were computed by dividing the comuted vapor pressures e_h by the saturated vapor pressures orresponding to the given temperatures.

TABLE 6.—*Examples of use of equation 12*

Groesbeck, Tex.—Autumn season				
h	t	f_h	e_h	Relative humidity
COMPUTED VALUES				
Km.	°*C.*		*mb.*	%
4.5	−1.4	0.1215	2.08	38
5.0	−4.3	.0971	1.64	38
5.5	−7.6	.0756	1.26	39
6.0	−11.0	.0575	.949	40
7.0	−18.3	.0310	.498	41
8.0	−26.2	.0152	.236	42
9.0	−33.7	.00671	.101	39
10.0	−40.5	.00270	.0396	33
11.0	−46.4	.000988	.0141	24
12.0	−51.4	.000328	.00458	14
13.0	−55.7	.0000988	.00135	7
14.0	−59.8	.0000270	.000363	3
15.0	−63.6	.0000067	.000089	1
OBSERVED VALUES (KITES)				
4.5	−1.3	0.1215	2.08	[1] 37
5.0	−3.8	.1013	1.72	35
5.5	−6.2	.0767	1.29	31

[1] Based on 35, 13, and 4 observations, respectively. Latter appears too low.

It is to be noted that computation makes the relative humidity a maximum near 8 km., which is the region of maximum average lapse rates found in the troposphere.

Similar comparisons for the other stations show that the great majority give reasonable values of humidities, a few giving some values which seem somewhat too large and a few giving values which seem too small. Drexel, Nebr., for autumn was among the former, and Washington, D. C., among the latter.

It is now necessary to integrate equation 12. This may be done by numerical integration, or more formally by expressing the function in an infinite series which is uniformly convergent and which hence may be integrated term by term. Still another method is to integrate by parts and express the resulting integral in terms of an infinite series by a process of continued integration (**9**). These methods are necessarily laborious. However, by making suitable transformations as shown in the following, the definite integral may be quickly computed from tables already in existence. To do this, equation 12 is converted to the more convenient exponential form

$$(13)\qquad f_h=f_d e^{-[c_2\kappa(h-d)^2+c_1\kappa(h-d)]}$$

where e = base of Napierian logarithms and $\kappa=\log_e 10=2.3026-$ = reciprocal of the modulus of common logarithms.

Completing the square in the exponent we get

$$(14)\qquad f_h=f_d e^{\frac{c_1^2\kappa}{4c_2}} e^{-\left[\sqrt{c_2\kappa}\,(h-d)+\frac{c_1\sqrt{\kappa}}{2\sqrt{c_2}}\right]^2}$$

This reduces to

$$(15)\qquad f_h=f_d 10^{\frac{c_1^2}{4c_2}} e^{-[\sqrt{c_2\kappa}]^2\left[h+\left(\frac{c_1}{2c_2}-d\right)\right]^2}$$

Letting

$$N=f_d 10^{\frac{c_1^2}{4c_2}}$$

$$a=\sqrt{c_2\kappa}$$

$$b=\left(\frac{c_1}{2c_2}-d\right),$$

the last equation simplifies to the form

$$(16)\qquad f_h=Ne^{-a^2[h+b]^2}$$

The desired integral is

$$(17)\qquad \int_d^H f_h dh=N\int_d^H e^{-a^2[h+b]^2}dh$$

where H is the upper limit of integration.

From the geometry of the respective curves it becomes evident that

$$(18)\qquad N\int_0^{h_1} e^{-a^2(h+b)^2}dh=N\int_0^{h_1+b} e^{-a^2h^2}dh-N\int_0^b e^{-a^2h^2}dh$$

where h_1 is any upper limit of integration. But since obviously

$$(19)\qquad N\int_d^H e^{-a^2(h+b)^2}dh=N\int_0^H e^{-a^2(h+b)^2}dh-N\int_0^d e^{-a^2(h+b)^2}dh,$$

on substituting equation 18 into the right-hand members of equation 19, respectively, we get

$$(20)\qquad N\int_d^H e^{-a^2(h+b)^2}\,dh = N\int_o^{H+b} e^{-a^2h^2}\,dh - N\int_o^{d+b} e^{-a^2h^2}\,dh.$$

Let $t = ah$
then $dt = a\ dh$
and $dh = \dfrac{dt}{a}$, whence we have

$$(21)\qquad N\int_o^h e^{-a^2h^2}dh = \frac{N}{a}\int_o^{ah=t} e^{-t^2}dt.$$

Substituting equation 21 in equation 20 we obtain

$$(22)\qquad N\int_d^H e^{-a^2(h+b)^2}dh = \frac{N}{a}\int_o^{a(H+b)} e^{-t^2}dt - \frac{N}{a}\int_o^{a(d+b)} e^{-t^2}dt.$$

There are numerous tables available of the definite integral (**10**):

$$\theta(t) = \frac{2}{\sqrt{\pi}}\int_o^t e^{-t^2}dt$$

much used in the Theory of Probability. To adapt equation 22 for the use of such tables we rewrite it in the form

$$(23)\quad N\int_d^H e^{-a^2(h+b)^2}dh = \left(\frac{\sqrt{\pi}}{2a}\right)N\left\{\frac{2}{\sqrt{\pi}}\int_o^{a(H+b)} e^{-t^2}dt - \frac{2}{\sqrt{\pi}}\int_o^{a(d+b)} e^{-t^2}dt\right\}$$

Noting that $a(d+b) = a\left(\dfrac{c_1}{2c_2}\right)$, we have finally for the special case where $H=\infty$ and $a \neq 0$, that

$$(24)\qquad F_d^\infty = N\int_d^\infty e^{-a^2(h+b)^2}dh = \left(\frac{\sqrt{\pi}}{2a}\right)N\left\{1 - \frac{2}{\sqrt{\pi}}\int_o^{a\left(\frac{c_1}{2c_2}\right)} e^{-t^2}dt\right\}$$

where

$N = f_d 10^{\frac{c_1^2}{4c_2}}$
$a = \sqrt{c_2\kappa}$
$\kappa = 2.3026-$, the other values as shown in Tables 4 and 5.

Table 7 (column F_d^∞) shows the results of integration for the higher strata, according to equation 24. Taking the upper limit as infinity introduces no significant error. The corresponding integrals for the lower strata are also given as well as the sums of the two respective integrals.

TABLE 7.—*Values of the factors F applying from the surface to the limits of the atmosphere*

Station	Spring				Summer			
	d	F_s^d	F_d^∞	[1] F_s^∞	d	F_s^d	F_d^∞	[1] F_s^∞
	Km.				*Km.*			
Broken Arrow, Okla	4.5	1,827	247	2,074	4.5	1,805	229	2,034
Drexel, Nebr	5.0	1,996	215	2,211	5.0	1,863	245	2,108
Due West, S. C	4.0	1,766	271	2,037	4.0	1,833	380	2,213
Ellendale, N. Dak	5.0	1,995	198	2,193	4.5	1,804	346	2,150
Groesbeck, Tex	4.0	1,655	311	1,966	4.5	1,785	272	2,057
Leesburg, Ga	3.0	1,597	485	2,082	2.5	1,475	694	2,169
Naval Air Station, Washington, D. C	3.5	1,812	363	2,175	3.5	1,732	289	2,021
Royal Center, Ind	4.0	1,750	309	2,059	4.0	1,689	263	1,952

Station	Autumn				Winter			
	d	F_s^d	F_d^∞	[1] F_s^∞	d	F_s^d	F_d^∞	[1] F_s^∞
	Km.				*Km.*			
Broken Arrow, Okla	4.5	1,822	183	2,005	4.5	1,989	338	2,327
Drexel, Nebr	6.0	2,228	149	2,377	4.5	2,347	411	2,758
Due West, S. C	3.5	1,751	526	2,277	4.0	1,979	375	2,354
Ellendale, N. Dak	5.0	2,132	236	2,368	5.5	2,658	204	2,862
Groesbeck, Tex	4.5	1,804	213	2,017	4.5	1,936	309	2,245
Leesburg, Ga	3.5	1,681	348	2,029	3.0	1,655	519	2,174
Naval Air Station, Washington, D. C	3.0	1,710	369	2,079	3.5	2,097	488	2,585
Royal Center, Ind	4.5	1,855	241	2,096	4.0	1,986	443	2,429

[1] See equation 4″ following, and text immediately thereafter.

We may note that F_s^∞ according to its definition b equation 4′, or

$$(4'')\qquad S_s^\infty = K\ e_s\ F_s^\infty \text{ grams},$$

provides a means of computing approximately the mas of precipitable water vapor in a column one square mete in cross section and extending from the ground to th limits of the atmosphere. The function F_h^∞ is independ ent of the units in which the surface vapor pressure, e is expressed. The value K, however, for our purpose depends only upon the units in question. For conver ience, we note here that

$K = 1.060$ when e_s is in mm. mercury.
$K = 0.79507$ when e_s is in mb.
$K = 26.92$ when e_s is in inches of mercury.

It may be reiterated that the term F_d^∞ is only tent tive. More reliable results can only be obtained b means of direct spectroscopic observations (**11**) to d termine the desired values, or at least in part by mea of reliable aerological observations, particularly of h midity, to great heights.

To obtain the desired value S_x^h for a station at heig x differing from the height of the nearest of the 8 statio given herein, the surface vapor pressure e_x may be r duced to the corresponding vapor pressure at the surfa of the "datum station," e_s, by the use of Hann's equ tion for mountain stations, thus

$$(8')\qquad e_s = e_x\ 10^{\frac{(x-s)}{6300}}$$

In addition, the factor F_s^h obtained from Table 3 or must be reduced by the amount F_s^x obtained fro Table 3. Consequently, the final corrected value

$$(25)\qquad S_x^h = K\ e_x 10^{\frac{(x-s)}{6300}}\ (F_s^h - F_s^x) \text{ grams}.$$

V. DISCUSSION OF FORMULAS; SOURCES OF ERRORS

1. *Comparisons with other formulas.*—Hann (**12**) h found that by changing the constant of his equation, to make it conform more closely to conditions in the fr air (i. e. changing from 6300 to 5000) and neglecting t temperature factor $(1 + \alpha\ t_h)$, he gets what is equival to the expression,

$$(26)\qquad S_o^\infty = K\ e_o\ (2170) \text{ grams}.$$

The value in parenthesis compares closely with t average of the corresponding factors given in Table Humphreys (**13**) has found from 74 balloon observatio made in Europe that the yearly average for *clear* day closely representable by what is equivalent to the pression

$$(27)\qquad S^\infty = K\ e_s\ (1930) \text{ grams},$$

approximately, where h_s averaged between 200 and meters. Here the agreement is reasonably close w the values for the warmer seasons—i. e., seasons w minimum cloudiness.

Fowle's spectro-bolometric observations on Mo Wilson (**11**) showed the mean value of F to be appro mately half way between Hann's and Humphreys' val or $F_o^\infty = 2040$ nearly, using Hann's equations for reduct to sea level. This value is based on observations m

ring the months June-September, inclusive, 1910 and 11.

2. *Sources of error in the formulas and results.*—As may adily be seen from the foregoing, the original assumpns that the ratio $\left(\frac{e_h}{e_s}\right)$ and t, or f_h, are explicit functions height reduce to the proposition that the amount of ter vapor over any small area of earth's surface is ectly proportional to the vapor pressure at the surce. This is equivalent to saying that F_s^∞ is a constant lependent of factors other than the height s. This is course untrue, for obviously the value in question ries with time and with changing meteorological conions in the atmosphere.

Where the time limit is sufficiently extended, the relanships may be expected to hold quite closely provided at unusual meteorological deviations from the average ve not occurred. The relationship is also valid at nes when a close approximation to the statistical verage condition" prevails.

(a) *Checking of normal exchange.*—The apparentconancy of the ratio $\left(\frac{e_h}{e_s}\right)$ found under the circumstances scribed has its foundation in the combined operations convection, and mixing and diffusion of water vapor the lower atmosphere. When little convection and xing are occurring from the ground upward as may be e case where a strong inversion exists not far above ound, the average law of variation of this ratio with ight may be departed from considerably. The ground ay thus heat up, causing increased evaporation and us increased vapor pressure, while almost no exchange taking place between the ground layer and the layers ove the inversion. The conditions above the inversion ay consequently be largely tempered by the winds at ose levels and regions from which the winds are blowing.

The relation which obtains between aqueous vapor two levels in a convecting mass of air in which connsation and mixing has not yet taken place may be pressed simply by the equation

$$\frac{e_2}{p_2}=\frac{e_1}{p_1} \tag{8}$$

here e_1, p_1 are the vapor pressure and barometric presre respectively at the original level, and e_2, p_2 are the rresponding values at a subsequent level. As an exame of the average distribution of vapor pressure in the wer layers of the troposphere, we may cite the empirical uations found for average values during the spring ason at Drexel, Nebr.,

$$\frac{e_h}{p_h}=\frac{e_s}{p_s}10^{-c_3(h-s)} \tag{9}$$

hich applies from the surface $h\equiv s=396$ m. to $h=750$ m. bove sea level) and,

$$\frac{e_h}{p_h}=\frac{e_d}{p_d}10^{-c_4(h-d)} \tag{10}$$

hich applies from $h\equiv d=750$ m. to $h=3500$ m., c_3 and c_4 ing constants.

rom the data at hand we find

$c_3=1.625\times10^{-4}$ (for h in meters)

$c_4=1.231\times10^{-4}$ (where $d=750$ m.)

nd $\frac{p_d}{p_s}=0.958$.

These relationships show that, statistically, convection, turbulence and diffusion with the resultant mixing and condensation cause the ratios $\left(\frac{e}{p}\right)$ not to remain constant with height but to decrease in geometric ratio with increasing height.

It may be noted that in this case since $c_3>c_4$, the ratio in question decreases more rapidly from the ground (396 m.) to the height 750 m. above sea level than it does from 750 m. to 3,500 m. The effect of temperature lapse rates may now be seen from the values given in Table 8 following.

TABLE 8.—*Mean spring lapse rates, Drexel, Nebr.*

Interval	$-\frac{\Delta t}{\Delta h}$, °C./100m.	Interval	$-\frac{\Delta t}{\Delta h}$, °C./100m.
m.		*m.*	
396–500	0.67	1,500–2,000	0.44
500–750	.60	2,000–2,500	.52
750–1,000	.40	2,500–3,000	.56
1,000–1,250	.36	3,000–3,500	.58
1,250–1,500	.36	3,500–4,000	.58

It is evident from these values that convection is here relatively stronger in the first 350 m. above ground than above that height. The small lapse rates from 750–2,000 m. are due statistically to the inversions prevalent over northern stations during winter and early spring (**14**). Thus, as the generally moist ground warms up in spring, convection and turbulence raise considerable water vapor from the layers adjacent thereto, carrying it up to the region of small or inverted lapse rates where the convection is checked. From there the water vapor, tends to slowly diffuse upward, aided somewhat by the higher (gradient) wind velocities occurring at those levels, but since lapse rates in these layers are below adiabatic, eddy diffusion carries a portion of the water vapor back toward the ground layers. In addition, since the ground is comparatively moist in this season due to the after effects of the winter frost and snow cover, evaporation proceeds very rapidly near the ground especially during clear days, often adding water vapor to the ground layers more quickly than it can be carried aloft. This explains why the ratio $\left(\frac{e}{p}\right)$ decreases more slowly in the layer from 750–2,000 m., than it does immediately below it.

The concept under consideration is perhaps further verified by comparing the variation of these ratios with height for winter and summer at Ellendale, N. Dak.

Figure 19 shows plots of $\left[h, log_{10}\frac{e}{p}\right]$ for the two seasons in question. The Summer curve is perhaps typical of average conditions when the stirring processes of the atmosphere have full play. The Winter curve shows the influence of the inversion in the lower layers. The mean seasonal lapse rates are shown by the small figures adjacent to each interval of height. The inversions in question are largely the result of the frequent "anticyclonic weather with its clear skies and intense radiation" (**6**) observed in these regions. The strong cooling of the lower layers due to radiation after sunset produces a subsidence of the air which thus becomes dynamically warmed. The continued cooling of the ground finally causes the temperature of the air at that level to become lower than that of the free air immediately above. The water vapor brought down by the subsidence of air thus finds itself in a region of diminished lapse rate and finally in an inversion. Convection is effectively checked under

such circumstances and the relative proportions of the constituent gases of the atmosphere tend to become fixed in amount. The evaporation of liquid or solid water falling through the inversion provides an important source of water vapor for the inversion layer when precipitation occurs. The water vapor, being less dense than dry air tends to diffuse molecularly toward the top of the inversion. Eddy diffusion, however, under the influence of increased wind velocities in the inversion layer plays an opposing rôle in the mechanism of the process, aiding in the general mixing of this constituent largely in the downward direction. The facts just adduced explain in part why the curve for winter is nearly vertical from the ground to about 1,000 m. elevation above.

Since molecular diffusion in the absence of convection and turbulence is relatively slow as an agency for dissi-

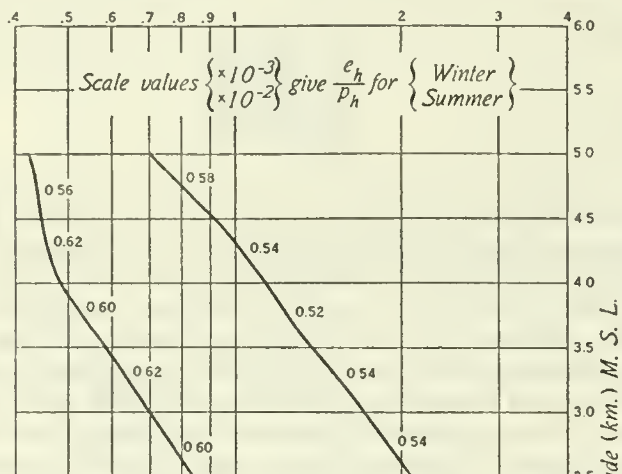


FIGURE 19.—Ellendale, N. Dak. Summer and winter. $\operatorname{Log}_{10}\left(\frac{e}{p}\right)$ plotted against height. Small figures adjacent to curves are mean lapse rates for interval in °C./100 m. The winter values are less in absolute magnitude than the summer values. Winter surface value, $\left(\frac{e_s}{p_s}\right)=0.00275$; summer surface value, $\left(\frac{e_s}{p_s}\right)=0.0170$

pating water vapor, under the conditions outlined above, changes in the surface vapor pressure, say, due to surface heating at sunrise, are bound to take some time in making themselves felt at higher levels. It may also be noted that the higher temperatures in the inversion increase the capacity of the space for water vapor so that relatively large amounts of vapor may be present without condensing.

Thus, cases of abnormally large factors F_r^∞ observed by Fowle at Mount Wilson (**11**), height 1,730 m., may be due to the forced convection of a stratum of air over the mountain, the air being of oceanic origin and having a strong inversion and low humidity at the height in question. Such conditions are very common in the Summer on the California coast (**15**). Thus with near normal moisture content in the free air above but low vapor pressure at the mountain top and an inversion just above it to prevent normal convection, the factor in question would become abnormally large.

(*b*) *Diurnal variation in relative distribution of water vapor with height.*—As is well known the diurnal march of vapor pressure at the surface generally shows a regular periodic variation. Inland regions in summer show two maxima and two minima, occurring at about 6 to 9 a. m. and 8 to 9 p. m., for the former, and 3 to 4 p. m. and 3 to 4 a. m., for the latter (**12**[b]). In general, the oceans in summer and winter and most inland regions in winter show but one maximum and one minimum, similar to the diurnal march of temperature, the maximum occurring during the afternoon and the minimum during the early morning. Coastal stations show variations between the extremes outlined above, but resemble the oceans most closely.

The causes of this diurnal march of absolute humidity at the surface are substantially as follows. In *summer*, at *inland* stations, the ground at dawn is greatly cooled due to the nocturnal radiation, especially so if the night has been clear. The subsidence of the air during the night due to this cooling and to the relative absence of convection carries much moisture down to the ground layers from the atmosphere. These two processes conduce to the process of condensation near the ground, and the formation of dew, especially if vegetation is present. Hence the low temperatures near the ground cause the space to have a smaller capacity for water vapor and also cause the removal under proper circumstances of much of the water vapor by condensation, producing a minimum of vapor pressure and absolute humidity near the ground just before dawn. This is the so-called secondary minimum.

As the sun rises, it warms the ground and evaporates much moisture. The lapse rates at first are insufficient to cause much instability hence the vapor pressure rises to the primary maximum occurring between 6 and 9 a. m. The "nocturnal inversion" frequently found not far above ground also aids by acting as a sort of ceiling to prevent the moisture from diffusing rapidly aloft. When the sun gets higher, the lapse rates increase near the ground, and often the "nocturnal inversion" disappears or rises higher in a less marked state. Thus convection becomes active, carrying much water vapor away from the ground layers. By the time the afternoon maximum of temperature has been reached, the supply of surface ground water has been greatly depleted and the rate of evaporation from the ground has become less than the rate at which the ascending air currents and eddies carry the moisture aloft. Hence we have the primary minimum of vapor pressure (and absolute humidity) at the surface occurring about mid-afternoon in the summer at inland stations. The evening (secondary) maximum occurs as a result of the rapid subsidence of air at dusk or shortly thereafter when convection has greatly diminished, and also as a result of the comparatively small decline in temperature near the ground.

Tropical stations in general present the characteristics described above all the year round.

Over the ocean in summer and winter the sun does not warm the water very rapidly and the diurnal amplitude of temperature is small, hence no rapid increase of evaporation can take place immediately after dawn and the morning maximum is absent. As the altitude of the sun increases, the rate of evaporation increases. Since an indefinitely large supply of water is available, and for other less important reasons not presented, the evapora-

tion can provide more water vapor than is removed. Hence we have an afternoon maximum. The evening maximum is also absent, here largely because the great ocean mass and slow change of water temperature prevent marked changes in surface evaporation, and decrease the tendency for sudden subsidence. The minimum occurring before dawn results from nocturnal cooling of the surface water and lower strata of air. Coastal and island stations are greatly influenced by the ocean and in general show the same type of diurnal march of surface vapor pressure.

At inland stations in winter the diurnal amplitude of temperature is usually comparatively small; and generally a considerable amount of surface ground water is available, either in the form of a snow-cover or ground frost. Also, inversions are quite prevalent over many temperate stations in winter (see Table 14), persisting in some cases throughout the day. These factors, and others, combined with the low altitude of the sun conduce to a slow and often small increase of vapor pressure at the surface from dawn to the afternoon maximum. Convection being relatively weak, the surface supply is little depleted thereby. The evening subsidence is comparatively less marked than in summer and ground temperatures are quite low, hence the evening maximum does not occur. The early morning minimum is caused by the same processes as were previously described.

With regard to mountains, the diurnal variation is similar to that of the free air some distance above the ground. Thus, convection carries moisture up the mountain sides from the valleys in the afternoon at about the time the sun is most effective in producing evaporation from the ground water and vegetation on the mountain slopes. Hence the maximum occurs in the afternoon, and the minimum before dawn when radiation has brought about considerable cooling and much of the moisture has been carried down by subsidence.

On low hills it is possible for the valley effect to preponderate over the free-air effect and the diurnal variation of surface vapor pressure thereon to resemble somewhat that of the valley.

Similarly the vapor pressure in the free air has a periodic diurnal variation. The data presented by Hann (loc. cit. p. 253) for the diurnal march of vapor pressure on mountain tops shows that for moderate heights (2,700–3,700 m.) there is a maximum occurring between 1 and 5 p. m. in the afternoon and a minimum occurring in the early morning from 2 to 6 a. m. With regard to the diurnal variation of absolute humidity over Mount Weather, 526 m. above sea-level and 374 m. above the valley floor (**16**), Blair (**17**) has stated that—

> With the exception of the surface and 1-kilometer levels in the summer half of the year and the 2.5 and 3 kilometer levels in the winter half of the year, the maximum moisture content of the air is found shortly after noon and the minimum shortly after midnight at all levels (526–3,000 m.) and in all times of the year. At the four levels mentioned the maximum moisture content is found just before noon.

An examination of the curves of the diurnal variation of absolute humidity over this place shows that a close approximation to the mean value for the day prevails between the hours 7 to 10 a. m., i. e., the time of day represented by the data given in Tables 2, 3, and therefore most probably also Table 7. This is also borne out by Süring's data (**2**, p. 162) from balloons and Hann's data from mountain stations.

It is evident from the foregoing that for a low-lying station in summer if the total amount of water vapor in a column of air of given cross-section is greater in the early afternoon than in the period 7 to 10 a. m., and also the surface vapor pressure is less in the early afternoon than in the morning, then the factor $F_{\circ}^{\infty}$ applicable to the afternoon should be greater than that for the morning. In winter, since the surface maximum of vapor pressure falls in the afternoon, the opposite of this may be true, particularly where a snow cover exists. Likewise for mountain stations, either of these conditions may obtain, depending on the height, since if the mountain is sufficiently high the maximum surface vapor pressure occurs in the afternoon. This then introduces another source of error in the use of the factors given, indicating that both diurnal and altitudinal corrections are necessary where they are to be used for times and heights other than those for which the data apply.

To obtain an approximate quantitative idea of the error arising from diurnal variations, the data presented by Blair (loc. cit.), for Mount Weather, Va., showing the diurnal variation of temperature and absolute humidity for the surface (526 m.), and the levels for every 500 m. interval from 1,000 m. to 3,000 m. inclusive, all above sea level, were used to compute the respective values of F_{526}^{3000} for two seasons and two times of day each. The seasons given were summer, represented by the 6-month period April–September inclusive, and winter, represented by the period October–March inclusive. Table 9 shows the results of the computations.

TABLE 9.—*Diurnal variation of F., Mount Weather*

Summer		Winter	
Time of day	F_{526}^{3000}	Time of day	F_{526}^{3000}
8:30 a. m.	1,251	8:30 a. m.	1,434
4:00 p. m.	1,389	3:00 p. m.	1,392

The earlier times of day used are closely representative of the average time of flights upon which the data given herein are based. The later times are approximately the times of maximum water-vapor content of the air column in question. A comparison of the values shows that in summer the value F_{526}^{3000} is 11 per cent greater at the afternoon maximum, and in winter 3 per cent less than at the 8:30 a. m., average condition. Since the vapor pressure at Mount Weather is tempered somewhat by the free air overlying the adjacent valleys, it is to be expected that a valley station would find the corresponding afternoon value more than 11 per cent greater in summer and not quite 3 per cent less in winter.

As is to be expected, the diurnal variation of absolute humidity is relatively small at 3,000 m. and probably is vanishingly small at 6,000 m. On this account the actual diurnal variation in $F_{\circ}^{\infty}$ during summer at a valley station may be expected to be slightly smaller than the above value or of the same order of magnitude. This is also true for winter but to a much greater extent.

In the case of stations situated on fairly high mountains, the vapor content of the air column may average only slightly more in the afternoon than in the early morning. However, increased vapor content in the free air, increased evaporation from the mountain sides with increased insolation, and forced convection of humid air up the slopes during the afternoon cause the surface vapor pressures in such cases to be disproportionately high compared to the free air some distance away. It is

thus obvious that the F_s^∞ for the afternoon under such circumstances averages lower than for the early morning (**11**). Since this is contrary to what obtains at valley stations in the summer, levels must exist at which the variations in the factor are comparatively negligible on the whole, particularly on mountain slopes. In this connection we may note that the mean value of F_{1730}^∞ found by Fowle for the late morning observations at Mount Wilson was but 73 per cent of the early morning value. These values were based on days during the summers of 1910 and 1911 when spectrobolometric observations were made (**11**).

In conclusion of this topic it may be said in the absence of other data that the factors F_s^h given herein are unsafe for use at mountain stations. For valley or plain stations at heights comparable to those of the eight base stations used, corrections for diurnal variation and height are necessary. It may be suggested that during the warm part of the year a diurnal correction be used, assuming tentatively say a 12 per cent increase in F_s^∞ at the afternoon maximum (3 to 4 p. m.), over the 8:30 a. m. average value, using proportionate amounts for intermediate times, if values for these times be desired. In the spring and autumn when convection is weak a smaller value than the above should be assumed, perhaps 5 per cent. In winter, the diurnal correction may be neglected or be assumed to have a small negative value (say 2 per per cent at the afternoon maximum), especially when the ground is rather moist. Southern stations in summer may have slightly larger values than the above.

Stations situated on slightly elevated terrain should use slightly smaller values than those given above.

(*c*) *Transient variations with weather types.*—The laws governing the genesis of the macroscopic meteorological systems of the atmosphere, the cyclone and anticyclone, in some manner not entirely clear, condition the relationships between the various meteorological factors to be observed in their vertical cross-sections, so as to bring about wide divergencies. This is particularly true of the relative vapor content found from level to level in a vertical section of the lower troposphere. To emphasize this point we reproduce in Figures 20–22, inclusive, curves of the function f_h as computed from mean vapor pressures and temperatures observed in different quadrants of well-pronounced HIGHS and LOWS at several stations. Sets of curves were chosen which showed the widest divergence in this respect among all the curves available from Samuels's study of aerological observations made in well-pronounced HIGHS and LOWS (**18**).

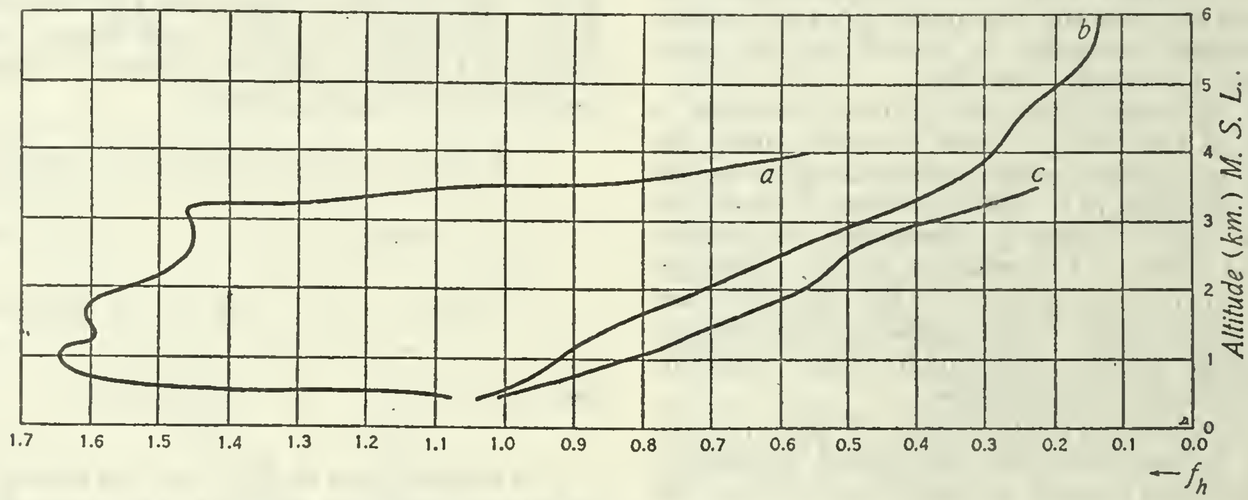


FIGURE 20.—Ellendale, N. Dak. Winter. f_h plotted against height. Curve a represents 2d quadrant of HIGHS; curve b, average of all sorts of conditions for the entire season; curve c, 3d quadrant of LOWS

The curves representing the average for all types of conditions are also shown by way of comparison. It is noteworthy that the curves for summer do not show such marked differences as found for the winter curves. Table 10 shows the comparative values of the integrals F_s^h for the curves given in figures 20–22, and also mean surface vapor pressures for each case.

TABLE 10.—*Examples of widely divergent values of F_s^h for special weather types in winter*

Station	Well-pronounced LOWS			Average of all types		Well-pronounced HIGHS			h
	Quadrant	$\bar{e}_s$	F_s^h	$\bar{e}_s$	F_s^h	Quadrant	$\bar{e}_s$	F_s^h	
		mb.		*mb.*			*mb.*		*m.*
Drexel, Nebr. (s=396 m.)	4	6.00	1,640	3.66	2,210	3	2.64	3,060	4,000
Ellendale, N. Dak. (s=444 m.)	3	3.57	1,850	2.56	2,170	2	1.09	4,580	3,500
Royal Center, Ind. (s=225 m.)	1	6.13	2,490	4.32	1,680	3	3.85	1,220	3,000

It should be noted that the values under LOWS and HIGHS in the table have less weight than the values in the central columns, mainly since they are based on fewer observations than the latter.

We may conclude from these values, however, that the transient variations of F^h are likely to be of such magnitude that serious errors may result if one attempts to compute the amount of water vapor in an air column at a particular moment from the average values of F_s^h given. This is most probably more true in winter than in summer. The use of average values may be safe for computing the average vapor content of the air column over a period of perhaps a season where a normal sequence of weather changes has occurred. In such cases the mean surface vapor pressure for the period must be used.

(*d*) *Errors due to sampling.*—As with every set of statistical variables where relatively few samples are taken for study, some uncertainty in the data must exist. Since the monthly means upon which the results are based were not in convenient shape to compute the probable errors, this index of the reliability of the means is not available. In all cases with the exception of the airplane flights at Washington, D. C., the means of ascent and descent were used. This method takes the diurnal variation into account and renders the final results more reliable. As stated before, where the observations are quite numerous as may be seen is the case for the lower levels at most of the stations (see Table 2), the results may be considered fairly reliable as averages.

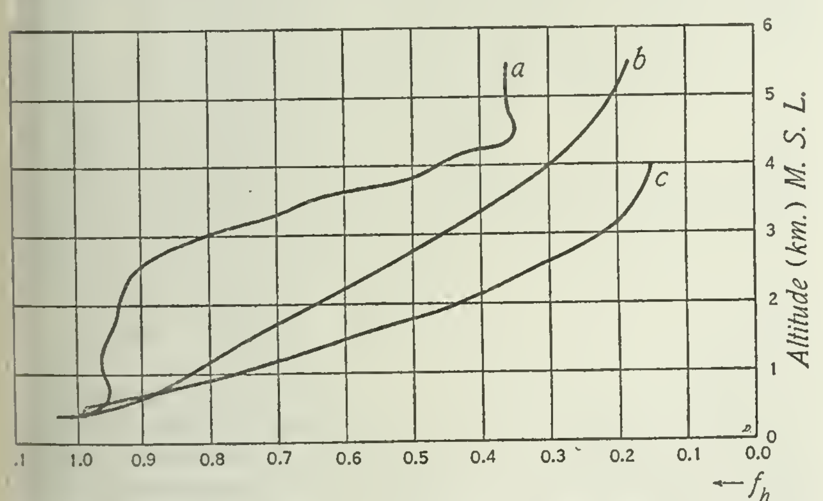
Several sources of error due to sampling creep in how-ver. Thus for example, since a certain minimum surface 'ind velocity is necessary before kites may be launched, ; is to be expected that calm days are not well repre-ented in the results. This is most likely to be true for he summer and autumn data and most pronounced in outhern stations where more days of calm prevail during hose seasons. This same effect causes the results to be ɛss reliable in the upper levels for these seasons. Like-'ise, days of very strong winds are not fairly represented ı the data. This is likely to be most effective at north-rn stations during winter and early spring. The former ource of error is not present in the case of airplane bservations.

In addition to the above, days of heavy or moderate ain or snow are not represented in the data. Days of ɔw overcast sky are also lacking from the airplane data, s are data for the interior of deep banks of clouds. Lite observations on the contrary frequently provide uch results.

The fact that the highest kite and airplane observations 'ere probably made on relatively dry days brings to ear a systematic error of uncertain magnitude in the alues for the higher levels.

Since nothing definite may be said regarding the mag-itude of the errors arising from the above sources, it is ecessary to leave the matter standing. It is felt how-ver, in the case of kite stations where observations are umerous that the errors, if important at all, are only 'orth considering in the southern stations during the ummer and perhaps the autumn seasons. The airplane ata for Washington, D. C., are probably more nearly epresentative on the whole of fair and partly cloudy onditions.

(*e*) *Errors in observed values.*—As is well known, the ıair hygrometers such as are used in kite, airplane and ounding balloon meteorographs are somewhat erratic in heir behavior and are often subject to considerable errors. The most important source of error is probably that due



F:GURE 21.—Drexel, Nebr. Winter. f_h plotted against height. Curve a represents 3d quadrant of HIGHS; curve b, average of all sorts of conditions for the entire season; curve c, 4th quadrant of LOWS

o the effect of the lag or inertia of the hygrometric ele-nent. The investigation of Kleinschmidt (4), on this hase of the question brought him to the conclusion that he factors which cause the greatest increase in the slug-gishness of the element are: (*a*) Low temperature, (*b*) low ıumidity, especially when the difference between the ıctual and recorded humidities is small, (*c*) rapid rate of hange of humidity with time as regards the instrument, (*d*) large number of hairs used in the element, (*e*) poor or ınequal ventilation, (*f*) poor quality or treatment of hairs. By far the most important factor of these seems to be temperature, for it is stated (loc. cit.), that—

> The temperature effect on the lag is small between +20° and +5° C.; from that temperature however, it increases rapidly, becoming infinitely great at −40° C., and almost completely reducing to nought the ability of hair to react to water vapor.

Despite objections recently raised to Kleinschmidt's methods (19), there is not much doubt that below −40° C., the hairs used, function more as a thermal element than a hygrometric element. This conclusion is amply

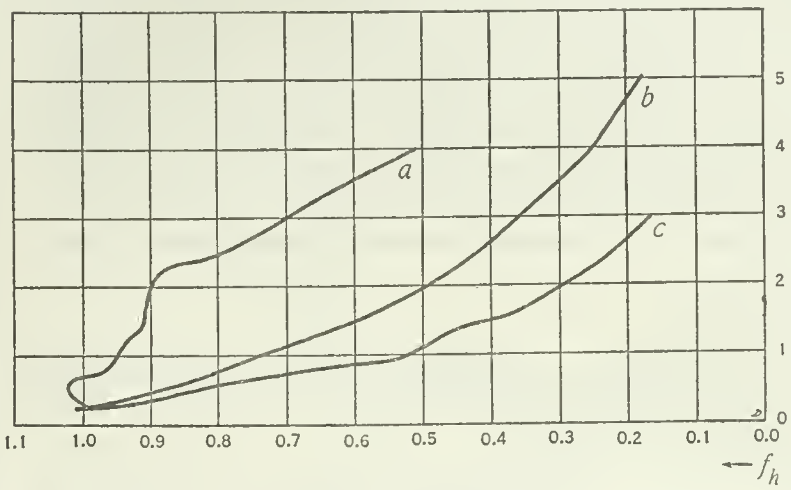


FIGURE 22.—Royal Center, Ind. Winter. f_h plotted against height. Curve a represents 1st quadrant of LOWS; curve b, average of all sorts of conditions for the entire season; curve c, 3d quadrant of HIGHS

supported by the indications of sounding-balloon observa-tions.

It should be remembered, however, that meteorological kites rise much more slowly on the average than either airplanes or sounding balloons and hence the hygrometric elements have a much longer time available in which to respond to the humidity of the air than is the case for the latter methods of observation.

The lag of the temperature element is quite small in the kite instruments used (20), hence mean vapor pressures based on kite observations probably are more reliable than any others extant, except possibly those obtained from manned balloons and carefully conducted airplane observations. Even here, however, they must be suffi-ciently numerous to form a satisfactory basis for reliable results. This feature of the problem causes the values for Leesburg, Ga., to be of much less weight than the remainder of the values, since the observations taken at that place were relatively few. Likewise the values for high levels, especially in winter and early spring, are probably much less reliable owing to the temperature effect.

(*f*) *Errors due to methods of computing results.*—As stated in a previous section (III), the method of differ-ences has been employed in computing mean monthly vapor pressures and temperatures. Since vapor pressure does not vary linearly with height, it is problematical whether that method is the proper one to use in obtaining means of that variable.

A consideration of the effects of the use of this method leads to the conclusion that if in the long run the higher observations are made on relatively dry days, as is quite likely, the computed mean vapor pressures for the higher levels will tend in the long run to be *higher* than the true means. The proper method to use is one based on the indications of the Theory of Probability and Errors considering the nature of the law of variation of vapor pressure with height. Thus far no satisfactory method that does not involve a prohibitive amount of work has been suggested, as far as known.

We thus have from these sources, errors due both to the method of computing and to a systematic limitation on sampling of data under all conditions.

In addition, another possible source of error may lie in the fact that the absolute humidity computed from the arithmetical mean of the daily observed absolute humidities for any given period may differ from the absolute humidity computed from the mean vapor pressure and temperature respectively for the same period (21). An examination of data for a number of months taken at random appears to show that for periods as long as a season the error in most cases falls well within the degree of accuracy of the individual observations and is of the order 1 to 2 per cent.

Probably the greatest source of error, if it is desired to use the function f_h (or F^h_s), to compute the absolute humidity at any given height from the mean surface vapor pressure for the season, results from the wide deviations of the daily ratios $\left(\frac{e_h}{e_s}\right)$ from the "mean" ratio $\left(\frac{\bar{e}_h}{\bar{e}_s}\right)$.

It is obvious from the nature of the function in question that the necessary condition that f_h give statistically correct results is that—

$$f_h=\frac{1}{n}\frac{273}{\frac{1}{n}\sum_{i=1}^{n}e_{s_i}}\cdot\sum_{i=1}^{n}\frac{e_{h_i}}{T_{h_i}} \tag{31}$$

where T_{h_i} = absolute temperature at height h, for the i-th observation and n = number of observations, the other symbols being as defined before, and the observations equally spaced in time. Tests on data for a number of seasons taken at random showed that percentage errors in the lower kilometer are usually quite small but are likely to increase above that height. For periods as short as a month the errors from this source may be very large for heights 2,000 m. above sea level and higher. In one case, viz, for March, 1926, at Ellendale, N. Dak., this error at the 3,000 m. level was 24 per cent of the average of the 16 observations available. When data for a full season are examined and compared, the percentage error resulting from the use of f_h for a height of say 3,000 m is found usually to fall within 7 per cent. Probably the errors would be quite serious for heights above 4,000 m.

Another source of errors falling within this category (f) is that arising from the use of hair hygrometer humidity readings and tables of saturation vapor pressures to compute current vapor pressures. In this method, the saturation vapor pressure corresponding to the observed current temperature is obtained from tables and multiplied by the relative humidity reading to give the current vapor pressure. For temperatures below 0° C., the tables used are those for the pressure of aqueous vapor over ice, while for temperatures above 0° C., the tables used are for vapor pressures over water. This arbitrary rule even though justified by expediency may be improper for use in the free air since for example water droplets may exist in the free air at temperatures far below the freezing point (22, 23). Thus, the hair hygrometer, calibrated at room temperature, when taken into the free air, yields a "number" which we call the "relative humidity." The definition of the latter term depends upon the form and kind of surface, whether water or ice, to the saturation vapor pressure of which at the given temperature we refer the actual vapor pressure to obtain the relative humidity. If for every case where temperatures below 0° C. are observed, we use the saturation vapor pressure over a flat surface of ice as the standard, and if liquid water is present in the atmosphere under the given temperature, then it is obvious that the "number" taken as the "relative humidity" may give erroneous results.

The following figures are illustrative. From the Smithsonian Physical Tables, seventh revised edition, we find for −16° C.,

1.315 mm. Hg. = saturation vapor pressure over water.

1.142 mm. Hg. = saturation vapor pressure over ice.

For 100 per cent relative humidity at this temperature with respect to water, the relative humidity with respect to ice is

$$\frac{1.315}{1.142}\times 100 \text{ per cent} = 115.1 \text{ per cent.}$$

For −30° C., Robitzsch (24) finds the corresponding value to be 133.2 per cent. It is obvious from these figures that if the "number" obtained from the hair hygrometer represents the relative humidity with respect to water say at −16° C., then this "number" must be multiplied by 1.15 to obtain the relative humidity with respect to ice. In other words the vapor pressure computed as in the past from the tables for the saturated vapor pressures over ice will be 15 per cent too small under these circumstances.

The above considerations are strictly applicable only for pure substances. However, water droplets in the free air are nearly spherical and contain hygroscopic nuclei which lower the vapor pressure. The importance of these nuclei in the mechanism of undercooling of water droplets has been much emphasized by Köhler (22). In addition, undercooled water particles of such smallness that they are invisible must exist in the atmosphere under certain circumstances and probably are quite prevalent in the vicinity of clouds [(22) (b) pp. 13–15, (25)]. These conditions complicate the problem to such an extent that considerable uncertainty exists as to what the "number" rendered by the hair hygrometer means physically. Therefore, little can be said on this point that can be considered conclusive; however, the shadow of doubt is thrown upon vapor pressures and values computed therefrom when obtained from hygrometer readings at temperatures below 0° C. This entire subject is greatly in need of intensive and critical investigations to provide practical and reliable means of obtaining accurate vapor pressure measurements in the free air.

(g). *Errors due to the use of equation 25 (for reduction of given data for use at neighboring stations).*—When equation 25 is used to compute the mean vapor content in the air column over a section other than one for which data is given herein, the largest error likely to result is that due to geographical interpolation. Thus, values computed from the three nearest "datum stations" may show a considerable difference. This necessitates that the values be weighted according to climatological and physiographic considerations and also according to distance and direction of each station from the others. The percentage error arising from this source is obviously variable and depends somewhat upon the intimacy of the person using the formula with the nature of the region with which he is concerned. It may be mentioned here that a defect to be found in *all* formulas of this sort is that they cannot take into account local or geographical variations

The data given herein are therefore most advantageous for use in central and eastern United States since some cognizance may then be taken of these factors.

Other errors associated with the use of this equation depend on the differences between the absolute humidities existing in the free air over the "datum station" at given heights above sea level and those existing at the same heights above sea level over other stations. Several computations have been made to ascertain the magnitude of this error, using certain assumptions based on observational data. The percentage errors in these cases were found to be less than 3 per cent where the upper base of the column was as much as 5,000 m. and where $x=750$ to 1,500 m. above sea level.

Uncertainty regarding the most applicable value of the constant in Hann's equation, 8, likewise introduces the possibility of a further error. However, the value used (6,300) is considered to be the best value extant for this purpose, firstly, because it is based on mountain observations, and secondly, because it agrees well with values obtained from the data for the lowest kilometer over the stations used herein.

(h) *Miscellaneous errors.*—Among these may be mentioned (*a*) errors in the determination of e_s or e_x, (*b*) errors due to the effect of hygroscopic particles in the atmosphere, (*c*) error in the constant K depending on variations in the relative density of atmospheric water vapor to pure dry air.

As is well known, serious psychrometric errors may arise during the winter when subfreezing temperatures prevail, hence the surface vapor pressures must be determined as accurately as possible to reduce the error to a minimum.

Regarding hygroscopic particles, it may be said that very little is known as to their effect on hair hygrometers and errors resulting therefrom. In general it may be seen that hygroscopic nuclei permit of a larger moisture content in the air than would appear possible from theoretical considerations which disregard their presence (**22**). This brings in an error whose magnitude it is difficult to gage under present circumstances. As was mentioned before, this is one of the problems for the future.

The influence of electrical charges and ions may be of material importance in this regard.

Possible errors in the constant $K(=1.060$ for e_s in mm.) may be dismissed as of small importance compared to the other errors since they probably amount to but a few tenths of a per cent within the range of temperatures thus far observed in the troposphere (**26**).

It is necessary to emphasize here that the present study does not take into account the water which is present in the atmosphere in the liquid form. Although the mass of water vapor per cubic meter of cloud has been found always to exceed the mass of liquid water present in the same volume, the latter may become as great as 5 grams per cubic meter in the heaviest clouds as has been shown by the independent investigations of Conrad, Wagner, and Köhler (**27**).

VI. COMPARATIVE STUDY OF THE DATA

1. *The function* $f_h=\left\{\dfrac{\left(\dfrac{e_h}{e_s}\right)}{1+\alpha t_h}.\right\}$

(*a*) *Seasonal variation.*—A study of the values of f_h given in Table 2 shows that on the average the values are greatest in winter and least in summer, and usually for heights greater than several hundred meters above ground the autumn values are greater than the spring values. Also, it may be seen that the values for summer for certain levels (usually above 1.5 km.) are greater than the values for spring. In southern stations where this is most pronounced, the summer values even exceed the autumn values for certain levels.

The interpretation of the statement that f_h for a given level is greater for one season than for another is that the absolute humidity at that level is greater on a day during the first season than on one during the second season where the vapor pressure at the surface is the same in both cases.

The contrasts between the various seasonal values depend partly upon the temperature differences existing and partly upon actual changes in relative vertical distribution of water vapor. It is evident from the gas laws that for a given vapor pressure the vapor content of a

Figure 23.—Geographical locations of the eight stations used herein

given volume is greater at low temperature than at high temperature.

If the ratios $\dfrac{f_h}{f_s}$ be formed from the data given in Table 2, it will be seen that the ratios are greater in winter than in summer at the four stations Drexel, Ellendale, Groesbeck (note below), and Washington, D. C. The reverse is true for certain intervals of height at the other stations. The intervals where $\left(\dfrac{f_h}{f_s}\right)_{\text{summer}}>\left(\dfrac{f_h}{f_s}\right)_{\text{winter}}$ are:

Broken Arrow, from 250–500 m. to 2,000–2,500 m.
Due West, from 2,000–2,500 m. to beyond 4,000 m.
Groesbeck, from surface–250 m. to 500–750 m.
Leesburg, from surface–250 m. to beyond 4,000 m.
Royal Center, from surface–250 m. to 1,500–2,000 m.

It will be noted that Groesbeck shows this effect only slightly and that the winter ratios are greatest at stations where in general the winter inversions are most pronounced (see figs. 20–22, and also ref. (**18**)). Referring back to Section V, 2 (*a*), p. 461, a number of causes operating to produce this relationship in inversions have been discussed.

It may be added here that when convection and turbulence are most active, i. e., when lapse rates are near the

adiabatic, the water vapor distribution naturally shows a more nearly uniform manner of decrease with height than when inversions are present. In the latter case the tendency is for the water vapor to stratify within or just below the inversion and to show a sharp decrease just above it. We should therefore consider these factors as among the most dominant in producing the downward march of the water content of the upper troposphere from summer to winter and its concentration in the lower few kilometers in the latter season, particularly in regions farthest removed from the Equator.

(*b*) *Geographical variation.*—Since the stations used herein are not of equal elevation and since the periods of observations upon which the present data are based are not identical, nor, of equal length, nor of very great duration, comparisons between the several stations must be taken with some reservations. Such comparisons with respect to vertical position should, strictly speaking, be comparisons between data for equi-geopotential surfaces (28), or possibly even surfaces of equal gravity potential above ground. Unfortunately, reduction of the data to such surfaces involves a large amount of additional labor. Such reductions are of course more important for high levels and for extensive latitudinal differences, but since the reliability of the data scarcely justified this refinement they were not undertaken.

The latitudinal variation of f_h may be seen by a comparison of the data for Ellendale, Drexel, Broken Arrow, and Groesbeek in order. The function shows a progressive decrease from north towards south at all levels in the lower 3–4 or so km. over these stations. Above these heights the relationship is not so consistent but signs of a reversal are evidenced. Comparing the data for Washington, D. C., and Due West, it would appear that f_h for the former is less at all levels during the summer and autumn, while during the other two seasons it is less only in the lower few kilometers but is greater above that height. Likewise, comparing Due West and Leesburg (data least reliable), it would appear that the data for Due West are greater at all levels in autumn and winter. During spring and summer however, f_h for the former is only greater from the surface to 2.5–3.0 km., the opposite being true above these heights.

Something regarding the longitudinal variation may be seen by comparing Drexel with Royal Center, Royal Center with Washington, Broken Arrow with Due West, and Groesbeck with Leesburg. Values of f_h at Drexel are found to be greater than those at Royal Center at all levels and all seasons. The relationship between Royal Center and Washington values is more complex. Speaking in general, the values at the former station are greater in the lower layers (surface to 750–2,500 m. depending on season), then the reverse is true for a thousand or more meters, and finally there is some evidence that at greater heights the Royal Center values are again greater.

Considering Broken Arrow and Due West, during summer and autumn for heights beyond the lower half kilometer or so, the Due West values of f_h appear greater than the Broken Arrow values. During the other two seasons, this is only true to heights between 2.5–3.0 km., a reversal of the relationship appearing above these limits. Groesbeck values show themselves to be greater than the Leesburg values in the lower kilometer or so (roughly speaking) but less above these heights in all seasons except autumn which has a more complex connection.

The interpretation of such relationships as are described above has already been given in the preceding section (*a*). Attention is invited to the fact that the values of f_h particularly for the lower levels appear to be smaller for stations near bodies of water than for inland stations considerably removed therefrom. This relationship is most pronounced in the North. This circumstance may be largely due to other local conditions [1] and hence must be investigated further to obtain verification or disproof of such a general conclusion.

2. *The average absolute humidity aloft.*—$\overline{W}_h = K\bar{e}_s f_h$, *g./m.*^{3}

(*a*) *Seasonal variation.*—Table 11 has been computed according to the above equation from data given in Table 2.

TABLE 11.—*Geographical and seasonal variation of absolute humidity (g./m.^{3})*

Height above sea level (m.)	Ellendale (444 m.)	Drexel (396 m.)	Broken Arrow (233 m.)	Groesbeck (141 m.)	Royal Center (225 m.)	Washington (7 m.)	Due West (217 m.)	Leesburg (85 m.)
SPRING								
Surface	4.90	6.32	9.11	11.51	6.77	7.44	9.10	11.10
250	-------	-------	9.03	11.06	6.67	6.74	8.96	10.26
500	4.77	6.01	8.02	9.99	5.81	6.02	8.02	9.33
750	4.22	5.35	7.23	9.05	5.23	5.39	7.32	8.59
1,000	3.84	4.86	6.61	8.03	4.75	4.95	6.75	7.93
1,250	3.52	4.41	5.94	6.97	4.29	4.58	6.19	7.27
1,500	3.22	3.99	5.28	5.94	3.89	4.27	5.59	6.54
2,000	2.65	3.25	4.16	4.40	3.19	3.53	4.40	4.84
2,500	2.16	2.69	3.30	3.48	2.47	2.82	3.37	4.14
3,000	1.72	2.24	2.68	2.86	1.95	2.21	2.56	3.36
3,500	1.37	1.83	2.21	2.36	1.57	1.80	1.97	3.04
4,000	1.07	1.49	1.77	1.99	1.27	1.36	1.58	2.78
SUMMER								
Surface	11.74	13.84	16.84	18.26	13.68	15.84	16.17	17.89
250	-------	-------	16.70	17.70	13.51	14.46	15.95	16.71
500	11.40	13.09	14.94	16.19	11.99	12.92	14.39	15.48
750	10.05	11.57	13.51	14.29	11.02	11.66	13.23	14.67
1,000	9.09	10.53	12.34	12.43	10.20	10.60	12.25	13.55
1,250	8.25	9.62	11.21	11.03	9.32	9.69	11.26	12.27
1,500	7.44	8.71	10.13	9.86	8.37	8.96	10.25	10.92
2,000	6.05	7.12	8.16	7.95	6.51	7.54	8.39	8.84
2,500	4.99	5.77	6.46	6.49	4 84	5.95	6.85	7.27
3,000	4.04	4.66	5.18	5.33	3.68	4.51	5.56	6.47
3,500	3.32	3.76	4.15	4.39	2.79	3.45	4.60	5.63
4,000	2.74	2.99	3.30	3.62	2.16	2.52	3.73	5.14
AUTUMN								
Surface	5.83	7.27	10.19	12.80	8.51	10.18	10.34	13.47
250	-------	-------	10.12	12.36	8.42	9.29	10.18	12.73
500	5.72	6.97	9.14	11.30	7.55	8.49	9.23	11.82
750	5.22	6.31	8.31	10.31	6.91	7.79	8.48	10.90
1,000	4.77	5.78	7.64	9.23	6.27	7.23	7.88	9.92
1,250	4.33	5.29	6.97	8.19	5.65	6.68	7.21	9.04
1,500	3.93	4.84	6.25	7.29	5.05	6.12	6.55	8.00
2,000	3.26	4.01	4.84	5.61	3.99	4.93	5.20	5.95
2,500	2.73	3.36	3.71	4.32	3.14	3.81	4.14	4.36
3,000	2.27	2.77	2.88	3.31	2.52	2.83	3.41	3.34
3,500	1.85	2.25	2.28	2.64	2.02	2.08	2.88	2.62
4,000	1.51	1.87	1.66	2.06	1.46	1.42	2.45	2.33
WINTER								
Surface	2.11	2.96	4.75	7.13	3.47	3.85	5.99	7.60
250	-------	-------	4.71	6.84	3.41	3.59	5.92	7.09
500	2.07	2.82	4.21	6.24	3.03	3.30	5.39	6.44
750	1.95	2.59	3.78	5.72	2.77	3.09	5.04	5.97
1,000	1.88	2.44	3.42	5.12	2.51	2.86	4.70	5.45
1,250	1.81	2.32	3.07	4.59	2.27	2.65	4.33	4.95
1,500	1.70	2.17	2.76	4.05	2.06	2.45	3.93	4.46
2,000	1.45	1.87	2.23	3.17	1.69	2.09	3.19	3.43
2,500	1.22	1.59	1.85	2.57	1.44	1.76	2.51	2.82
3,000	0.97	1.34	1.56	2.09	1.24	1.42	1.99	2.32
3,500	0.74	1.10	1.34	1.70	1.04	1 14	1.58	1.65
4,000	0.59	0.87	1.14	1.45	0.86	0.95	1.30	1.23

Comparison of the data by seasons shows that there is a progressive increase in absolute humidity from winter to summer and that the autumn values exceed the spring values at all the stations and for almost all the levels given. The levels 4,000 m. at Broken Arrow and 3,000–4,000 m. at Leesburg stand as exceptions (note data for latter station not very reliable).

(*b*) *Geographical variation.*—Figure 23 indicates the geographical location of the eight stations used. Com-

[1] See discussion on p. 455, Section IV, 2, regarding low temperature in the free air along the Atlantic Coast.

parisons of the stations presented in the first four and last three columns of Table 11 indicate the progressive increase of absolute humidity on going from north to south at all levels given. Broken Arrow, 4,000 m., autumn; Leesburg, 3,000–4,000 m., autumn; and Leesburg, 4,000 m., winter, stand as exceptions. The Leesburg values being based on few observations, are not very reliable and hence these exceptions are to be taken with reservations.

Comparing Drexel and Royal Center we find the values for the former to exceed those for the latter at all levels above 500 m. in spring, and at all levels in summer. During autumn the Drexel absolute humidities are less than the Royal Center absolute humidities from the surface to between 1,500–2,000 m. Above that height the Drexel values are greater. In winter the same relationship exists, only the height at which the reversal takes place lies between 1,000–1,250 m.

The relationships last presented appear anomalous at first sight, for one would be inclined to think that the proximity of Royal Center to Lake Michigan would render it more moist aloft than an inland station far removed from the lake and almost equidistant from the Gulf of Mexico. However, they may be traced back to the pressure gradients which normally exist over continental United States, and to the resulting air flow from different origins. Referring to Gregg's **(29, 6)** Aerological Survey of the United States (Mo. Wea. Rev. Supp. 26, pp. 55–56 and Supp. 20, pp. 39 and 45) it will be seen that in summer and spring the normal pressure gradients cause the resultant winds over Drexel to have a considerable southerly component while the resultant winds at Royal Center are more from the west and west-northwest. This brings about a greater transport of moist gulf air to Drexel than to Royal Center, and the latter must get a larger proportion of the relatively dryer polar air **(30)**. In winter and autumn the resultant winds at Drexel have a more northerly component than those for Royal Center and the relationship is partly reversed.

Comparisons of Royal Center with Washington, Broken Arrow with Due West, and Groesbeck with Leesburg bear out remarkably well on the whole what would be expected from considerations of the resultant air flow.

These facts emphasize the importance of studying the movement of air masses more closely **(30)**, both for forecasting purposes and for the study of comparative climatology.

3. *The integral,* $F_s^h = \int_s^h f_h dh$.—

(*a*) *Seasonal variation.*—Considering the values given in Table 3, it will be noted that the winter values are the largest. In northern stations the summer values are always least for the data given. In southern stations the summer values differ little from or exceed the spring values for h generally above 2,500 m., the summer values being less for h below that approximate height. Leesburg appears to show this difference at even lesser heights. The autumn values exceed the spring values in every case where the data are relatively reliable. Leesburg above 3,000 m. may be an exception.

The interpretation of a statement that F_s^h for one season exceeds the corresponding value for another season is that on days when the surface vapor pressures are the same in both seasons, the day in the first season will have a larger total vapor content, $S^h{}_s$, in the air column from the surface to height h than will the day in the second season.

Some of the underlying causes of the differences indicated above have been previously discussed under Section VI, 1 (a).

(*b*) *Geographical variation.*—Since the values of F_h have not been reduced to a common datum surface, they are not strictly comparable. However, since it so happens that the group of stations Ellendale, Drexel, Broken Arrow, and Groesbeck have lower surface elevations above sea level in descending order respectively, some valid conclusions may be drawn from the data given. An inspection of the values for these stations indicates that in the higher levels at least, the values decrease from north to south, despite the opposing effect of decreasing surface elevation in the same direction. Hence it may safely be concluded that if the data were reduced to a common datum surface, the values, for h (the upper limit of the column) equal to say 4,000 m., would decrease from north to south. This is in accord with the general latitudinal variation found for f_h, and is most pronounced in the winter seasons as was found for the latter.

In a similar manner we note that the Drexel values exceed the Royal Center values, particularly for the higher levels.

4. *The average total vapor content of the air column.*—$\bar{S}_s^h = K\bar{e}_s F_s^h$.

(*a*) *Seasonal variation.*—As was found for the seasonal variation of absolute humidities, the values $\bar{S}_s^h$ from Table 3 may be seen to increase from winter to summer, with summer having the maximum values. The autumn vapor content exceeds the spring content in every case. The greatest contrast between summer and winter content is found in northern stations and the least in southern stations. Comparing the values for $h = 4{,}000$ m. for the various stations, it is seen that the spring content is about 0.5 the summer content in northern stations and slightly more (roughly 0.6) in southern stations. For the same upper limit, the average winter content is about 0.25 the average summer content in northern stations. The proportion increases as one goes southward, being near 0.4 at Groesbeck and Leesburg.

The relatively smaller difference between the vapor content during these two seasons in the southern stations as compared with the northern stations is partly due to the smaller contrast between winter and summer with respect to total solar radiation received at the southern stations as compared with the northern stations (31). This produces a smaller amplitude of the mean free-air temperature variation between winter and summer at southern stations as compared with northern stations. This in turn influences the relative capacity of the space for water vapor and also the relative evaporation from water surfaces and the soil. The nearness of the southern stations to bodies of water also brings to bear the tempering effect of the high specific heat and slow rate of cooling of the water.

With regard to the solar radiation received, it must be remembered that even though the intensity of the solar radiation received at the top of the atmosphere per day in summer differs little between stations at latitude 30° and 40° N., the amount received at the ground is markedly greater at latitude 40°, in fact the maximum on June 21 is received at about latitude 48° N. (sea level). This is brought about by the increasing length of day and decreasing vapor content from south to north, in spite of the lower altitude of the sun at midday at northern stations (32). It is thus seen that the water vapor blanket which is so effective in depleting the radiation received

at the top of the atmosphere and which must increase towards the Equator as the result of the cumulative effect of more intensive heating, itself must act as a tempering agent to diminish the difference between summer and winter at southern stations. The annual march of cloudiness, the variations of which at most places in temperate latitudes can not simply be attributed to solar radiation, will also be seen to be an important factor.

Despite the greater total radiation received in spring as compared with autumn (at sea level), the total vapor content was found to be greater during the latter season. This is largely the result of the after-effect of the preceding seasons in each case respectively.

The more frequent outbreaks of the relatively dry polar air in winter and spring must also be considered an important factor governing the seasonal variation of the vapor content of the air.

(*b*) *Geographical variation.*—Considering the values given in Table 3 for Ellendale, Drexel, Broken Arrow, and Groesbeck, despite the differences in surface elevation, it may be safely said that the total vapor content, $\bar{S}^h_s$, in general increases from north to south, as is well known. This is likewise shown by the stations to the eastward, if some allowance is made for differences in elevation.

Comparing Drexel and Royal Center values, it will be seen that despite the greater elevation of the former, the summer values for Drexel exceed those for the latter station at heights above the layer between 3,500 and 4,000 m. This agrees, of course, with the marked differences in absolute humidity found between the two stations for this season. A close analysis of the spring values for these stations appears to indicate that possibly for some height above 6,000 m. the total vapor content of the column for the former may differ very little from that for the latter, this in spite of difference in elevation. This is not so likely to be true in the autumn and winter. (See tables 7 and 2.)

Broken Arrow and Due West show very small differences in $\bar{S}^h_s$ for spring, but the difference becomes more and more marked until it reaches a maximum in winter. This is probably largely due to the seasonal changes in frequency and strength of the free-air winds and their places of origin. Thus in spring the most frequent winds at 1,000 m. above surface at both stations are from the Gulf of Mexico (**29**, p. 43). The summer months show a slightly smaller frequency from the northwest quadrant, with slightly more from the southwest at Due West. The winter months on the other hand at Broken Arrow have their most frequent winds at 1,000 m. from the southwest and northwest, i. e., from relatively dry regions, while at Due West the most frequent winds in this season are from the northwest, west, and southwest. The trajectories of air flow in the lower Mississippi Valley and in the Gulf region show that much of the air reaching the southeastern seaboard of the United States in winter (as well as in summer and spring, to a lesser extent in autumn) must have its origin in the Gulf of Mexico. Hence these circumstances are to be regarded as the secondary causes of the differences to which attention was called.

Groesbeck and Leesburg show similar characteristics, if some allowance is made for differences in elevation.

As was stated before, a factor to be considered in the study of the causes of the seasonal variation of the vapor content of the air column is the question of the frequency of outbreaks of polar air. This is also important with regard to geographical-seasonal variations. Thus in winter, spring, and late autumn outbreaks of continental polar-air are more frequent than in summer, late spring and early autumn. Since Ellendale, for example, is more nearly in the path of such outbreaks than any of the other stations, it is obvious that this cause will bring about a more marked variation in $\bar{S}^h_s$ between winter and summer at this station than at any of the others. Drexel and Royal Center are also likewise affected. On the other hand, the southern stations such as Groesbeck, Due West, and Leesburg will be much less affected by this cause, since in general the polar-air will have warmed somewhat by its passage southward, and will have had an opportunity to acquire more water vapor. Furthermore, the track of winter cyclones fed by polar-air is often such as to miss entirely the southern stations.

Hence it appears that the variations noted above may largely be explained in terms of solar radiation and air trajectories, these undoubtedly being conditioned by more basic phenomena such as: The revolution of the earth in its orbit; the inclination of the earth's axis to the plane of the ecliptic; the rotation of the earth about its axis; gravity; the physical properties of water in its various forms, as well as of air and earth; the relative distribution of land and water and other physiographic features; solar radiation, quality as well as intensity, as received at the top of the atmosphere; and others.

With regard to the influence of mountain barriers on the vapor content of the air column, the station which we would expect to be most influenced among those given herein is Washington, D. C. There is some evidence that in spring, summer, and autumn the mountain barrier to the west of that station is quite instrumental in partially depleting the vapor content of the air currents which frequently in those seasons flow up the Mississippi Valley from the Gulf of Mexico and recurve eastward toward the Atlantic Ocean. The same effect is produced in winter but here quite often the supply cut off at low levels is comparatively rich in water vapor at heights above the mountain tops, due to inversions, and hence it appears likely that the contrast in vapor content between this station and one to the west of the mountains would be more striking in the former three seasons than in winter. (Compare figs. 11–13.)

(*c*) *Discussion of* $\bar{S}^\infty_h$.—Table 12, which was computed from the factors F^∞_s given in Table 7 and the mean surface vapor pressures given in Table 2, shows the (tentative) approximate mean depth of water which would be formed if all the water vapor in the air column from the ground to the limits of the atmosphere were condensed instantaneously and deposited upon the ground. The values are given for each season and are expressed both in centimeters and inches. These values give a relative indication of the mean quantity of water vapor effective for absorbing solar radiation and earth re-radiation.

TABLE 12.—*Approximate mean depth of rain equivalent to total vapor content of air column from surface to outer atmosphere* ($\bar{S}^\infty_s$)

Station	Spring		Summer		Autumn		Winter	
	Cm.	*In.*	*Cm.*	*In.*	*Cm.*	*In.*	*Cm.*	*In.*
Broken Arrow, Okla	[1] 1.99	0.785	3.75	1.478	2.17	0.853	1.12	0.441
Drexel, Nebr	1.44	.569	3.16	1.245	1.80	.708	.80	.316
Due West, S. C	1.96	.773	3.92	1.545	2.50	.984	1.45	.570
Ellendale, N. Dak	1.10	.432	2.71	1.067	1.41	.557	.58	.229
Groesbeck, Tex	2.41	.950	4.12	1.622	2.76	1.086	1.65	.651
Leesburg, Ga	2.48	.976	4.29	1.688	2.97	1.169	1.73	.681
Washington, D. C	1.69	.665	3.49	1.372	2.23	.878	1.00	.394
Royal Center, Ind	1.45	.570	2.90	1.142	1.87	.735	.83	.329

[1] To obtain mass in kg., per column one sq. m. in cross section, multiply depth (in cm.) by 10. To obtain mass in metric tons per column one sq. km. in cross section, multiply depth (in cm.) by 10^4. To obtain mass in short tons (2,000 lbs.) per column one sq. mi. in cross section, multiply depth (in cm.) by 2.855×10^4.

It is clear from the values presented that the blanket-ig or "greenhouse" effect of the water vapor is more ffective by far in summer than in winter. Were it not or this blanket of water vapor in summer, it is obvious hat our days would be much more unbearable so far s temperature is concerned and the nights very cool. imilarly the smaller amount of water vapor in winter ends to reduce the amount of radiation absorbed by he atmosphere, hence making our winters relatively older on this score than our summers. That is, our olar climate generates a cycle of events which tends to ugment its effect in winter by its influence on ter-estrial moisture, and on the contrary in summer it ends to retard and conserve its effect by its influence n the same agent. This is probably an important actor in explaining the great contrast existing in winter etween polar and equatorial regions and hence the tronger gradients and more intensive circulation than n summer.

VII. SUMMARY

Tables have been introduced (2, 3, 7) for computing he average absolute humidities at various heights, and he total vapor content of m². columns extending from he ground to various heights above sea level, from the nean vapor pressures at the surface, for eight stations n the United States east of the Rocky Mountains.

An equation, 25, has been given to permit the use of he data given in tables 3 and 7 for other stations not oo distantly located from those given and physiographi-ally similar. The errors resulting from the methods mployed have been fully discussed. It is emphasized hat serious errors may result if the given factors are ised to compute the required vapor contents for periods f less than a season.

Under the discussion of errors, a number of topics of nore general interest have been treated. Among these nay be mentioned: The vapor distribution in inversions nd the mechanism involved (V, 2, a.); the diurnal vari-tion of absolute humidity near the surface, near moun-ains, and in the free air (V, 2, b.); errors due to the ise of hair hygrometers at low temperatures (V, 2, e.); rrors in vapor pressures computed from hair hygro-neter readings at temperatures below 0° C. (V, 2, f.)

The various data, viz. f_h, $\overline{W}_h$, F^h_s and $\overline{S}^h_s$ (see defini-ions in Sec. II), have been discussed with regard to heir seasonal and geographical variations. Special mphasis has been laid on the air trajectories and solar adiation to explain some of the differences found.

A study of the relationship between average precipi-ation, atmospheric water vapor content, and other actors has been begun. It may be stated at this time hat the mean precipitation is not directly proportionate o the mean vapor content but depends to quite an extent ipon other factors also. It is hoped to publish a paper n this subject in the future.

Acknowledgement is due to Mr. H. L. Choate of this livision for several stimulating discussions on topics argely related to air trajectories. Acknowledgment is also due to several members of the staff of this division for assisting in the computation of some of the early tables.

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SOLAR RADIATION AS A METEOROLOGICAL FACTOR [1]

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SYNOPSIS

Variations in the earth's solar distance cause variations in the intensity of solar radiation at the outer limit of the earth's atmosphere of very nearly 3.5 per cent on each side of the mean, with the maximum early in January and the minimum early in July.

Variations in solar declination cause seasonal variations in the daily totals of solar radiation as measured at the surface of the earth, which are small at the Equator, but increase rapidly with latitude. At Habana, Cuba, latitude 23° 09′ N., the average daily amount at the time of the summer solstice is about double that at the time of the winter solstice; at Washington, D. C., latitude 38° 56′ N., the corresponding ratio is about 3.5; at Stockholm, Sweden, latitude 59° 21′ N., it is about 20, and at Sloutzk, Union of Socialist Soviet Republics, about 40.

Following explosive volcanic eruptions the great quantity of dust thrown into the atmosphere, some of it to great heights, has diminished the intensity of the direct rays of the sun as received at the earth's surface from 15 to 25 per cent for periods of several months. Such explosions, with their accompanying dust clouds, occurred in 1883, 1888–1891, 1902, and 1912, and a slight cooling of the earth as a whole seems to have followed. On the other hand, there have been no such eruptions since 1912, or during a period of nearly 20 years, and Ångström is of the opinion that on account of the small amount of dust now present in the stratosphere the temperature of the earth should be slightly higher than usual.

For solar constant values it has been claimed that periodicities of from 68 to 8 months exist, with amplitudes of from 0.005 to 0.014 calories, or about 0.3 to 0.7 per cent of the mean value. Also, that there are short-period trends in values, with an average length of five days and an average amplitude of 0.8 per cent. To these short-period trends of less than 1 per cent in magnitude, have been attributed the "Major changes in weather."

A careful study of these various variations in the intensity of solar radiation leads to the conclusion that weather changes are brought about, not by short-period trends of less than 1 per cent, but by the manyfold difference in the intensity of the solar radiation received by the earth in equatorial and polar regions. As a result great temperature differences exist between these regions. Gravity causes the heavy cold air to displace the lighter warm air at the surface, and a polar-equatorial circulation is set up, turbulent in character, especially in winter when the temperature difference is most marked. Well-defined movements of this character are to be found on the weather maps of the different countries, and examples are shown in this paper in reproductions of weather maps for the United States. It is to studies of this turbulent polar-equator movement of air that meteorologists look for improvements in weather forecasting, and it is for such studies that the meteorological work of the Jubilee International Polar Year 1932–33 is now being organized.

INTRODUCTION

Although in this paper solar radiation is to be considered from the standpoint of the meteorologist, there are certain astrophysical and astronomical facts that also must be kept in mind.

Thus, astrophysical research has shown that the sun is a hot, luminous body, perhaps gaseous throughout, with its outer layers rotating about the solar axis at different rates in different latitudes. The quality of solar radiation is about that of a black body at a temperature of 6,000° A. This may therefore be taken as the effective temperature of the sun. The temperature of its center, on account of the enormously high pressure that must there prevail, is variously estimated to be from thirty to sixty million degrees.

The sun radiates, we are told, 3.79×10^{33} ergs of energy per second, corresponding to a loss of about 4,000,000 tons of mass per second. Of this vast amount of energy the planets and their satellites intercept about 1/120,000,000, and the earth about 1/2,000,000,000, or 4.1×10^{16} gram-calories per second.

What becomes of all the solar radiant energy except that intercepted by the planets and their satellites, and how the sun maintains this enormous output of energy without apparent impairment of its resources, while interesting problems, will not be considered here. Rather, we shall confine our attention to the one 2-billionth part that is intercepted by the earth, and which is of vital interest not only because it is the source and the support of all life on the earth, but also because it is the source of weather and climate.

ANNUAL VARIATIONS IN SOLAR RADIATION INTENSITY RECEIVED BY THE EARTH

The earth is at its mean solar distance of approximately 93,000,000 miles twice each year—in 1931 on April 4 and October 5. It was nearest to the sun on January 3, and farthest from it on July 6. The ratio of the longest to the shortest distance is 1.034, and since the radiation intensity varies inversely as the square of the distance from the radiating body, other things being equal its intensity early in January should have been nearly 7 per cent higher than in early July. Therefore solar radiation received by the earth has an annual variation in intensity of about 7 per cent, and we in the Northern Hemisphere are now favored by the fact that the maximum intensity occurs during our winter.

Besides the annual variation in the earth's solar distance there is also the annual variation in the sun's apparent declination due to the inclination of the earth's axis of rotation to the plane of the ecliptic, in consequence of which the position of the sun in the heavens coincides with the plane of the terrestrial equator at the time of the equinoxes only. From March 21 to September 21 the sun is north of the terrestrial equator, or its declination is north, and during the remainder of the year it is south. During the summer months, therefore, the sun's rays strike the surface of the earth in the Northern Hemisphere at a smaller angle from the vertical, and thus have a shorter path through the atmosphere during most of the day than during the winter months; also,

[1] Presented before Section B, A. A. A. S., at a joint session with the American Meteorological Society at New Orleans, La., on December 30, 1931.

the sun is above the horizon a greater number of hours. The reverse, of course, is the case in the Southern Hemisphere, which has its winter while the Northern Hemisphere has its summer.

Thus, from variations in the solar declination there results a second annual variation in the vertical component of solar radiation intensity, which variation itself varies in amount with latitude. In consequence, for the average daily totals of solar radiation as received on a horizontal surface the annual variation is slight at the Equator, at Habana, Cuba, the midsummer totals are about double those for midwinter, at Washington, D. C., they are 3.5 times as great, and at Stockholm, Sweden, and Sloutzk, Union of Socialist Soviet Republics, the ratios are 20 and 40, respectively.

ATMOSPHERIC DEPLETION OF SOLAR RADIATION

Besides the annual variation in solar radiation intensity due to the earth's position in its orbit, and that due to solar declination, there are irregular variations owing to changes in the constituents of the atmosphere. In general, these constituents may be divided into three classes, as follows:

(1) Atmospheric gases; (2) solid particles, principally dust; and (3) condensed gases, principally water.

The constituents of the atmosphere deplete the solar radiation that passes through it in three ways, as follows:

(*a*) Scattering by atmospheric gas molecules, the law of which has been developed in a workable form by Raleigh and King.

(*b*) Absorption by atmospheric gases, the laws for which have been determined by Fowle and others, so that the depletion may be computed provided we know the atmospheric content of each of the absorbing gases, of which the principal are water vapor, ozone, and carbon dioxide.

(*c*) Scattering by solid particles and condensed gases. Ångström has developed the law for scattering by dust

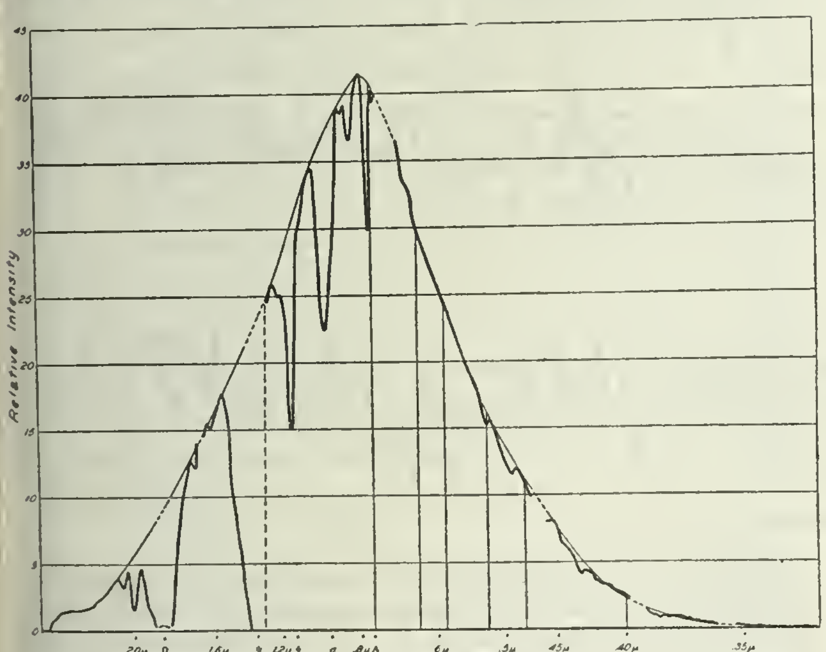

FIGURE 1.—Bologram of solar radiation

particles, provided their diameters are known, and has put it in a convenient form for computing. Unfortunately, atmospheric dust particles vary in size. Those due to explosive volcanic eruptions, and also dust particles from city smoke, average much larger in diameter than ordinary atmospheric dust, for which Ångström's law has been developed.

The extent of the depletion of radiation both by scattering and by absorption varies with the wave length. Therefore, for its determination spectro-bolometric measurements are necessary.

Figure 1 is a spectro-bologram of solar radiation obtained by the Astrophysical Observatory of the Smith-

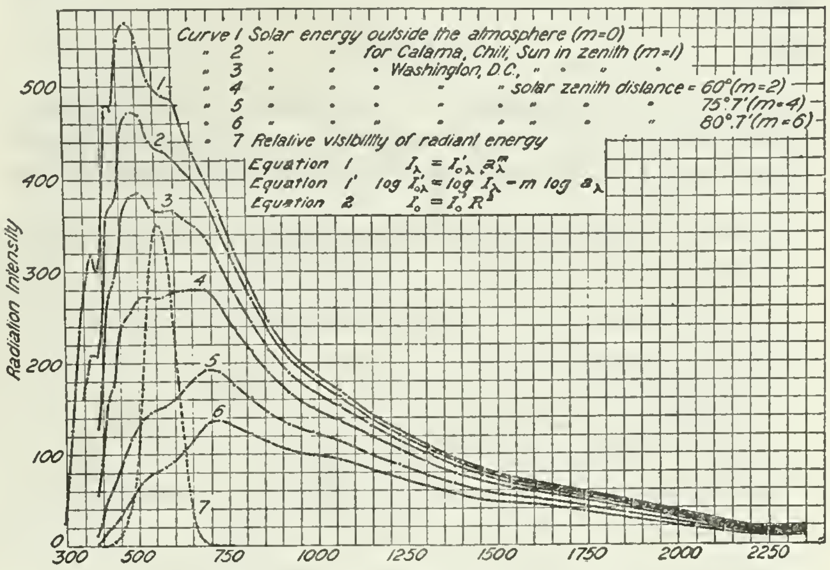

FIGURE 2.—Normal solar radiation energy curves

sonian Institution by means of a 60° ultra-violet crown-glass prism (**1**). Note the depressions in the curve caused by absorption of energy in the water-vapor bands. In one of these the position of the zero line of the curve has been redetermined. Note also that the wave-length scale is more open at the short-wave or ultra-violet end of the bologram than at the infra-red end. In Figure 2 the wave-length scale has been made uniform throughout and is reversed in direction from that in Figure 1, so that wave lengths here increase from left to right. In addition to the fact that the water vapor absorption bands are not here shown, the energy distribution with respect to wave length has been materially changed, so that for curve 1, "Solar energy outside the atmosphere" (**2**), the maximum intensity is in the blue. In curve 2 (**3**), for radiation intensities measured at Calama, Chile, and for curves 3 to 6, inclusive, for intensities measured at Washington, D. C. (**4**), with the sun at increasing angular distances from the zenith, the maximum of the energy curves is shifted successively from the blue through the green, yellow, and orange to the red, which indicates why, as the sun approaches the horizon, it often assumes a reddish hue.

However, the apparent color of the sun can not be determined from the wave length of the maximum of the spectrum energy curve alone. Curve 7, Figure 2, gives the relative visibility of radiant energy of different wave lengths. It has a decided maximum in the green, and from this it has been argued that if we could view the sun from outside the earth's atmosphere its color instead of being blue, as Langley claimed, would be green.

THE DETERMINATION OF THE VALUE OF THE SOLAR CONSTANT OF RADIATION

Spectrobolometric measurements of the intensity of solar radiation throughout the solar spectrum, made at the surface of the earth, form the basis for determinations of the intensity before it entered the earth's atmosphere. The theory of the determination is simple, but the observational work is tedious.

Referring to Figure 2, curves 4, 5, and 6 represent solar spectrum energy curves based on spectrobolograms ob-

tained with the sun at zenith distances 60. 0°, 75. 7°, and 80.7°. The corresponding length of the paths, m, traversed by the solar rays to reach the surface of the earth, expressed in terms of the length when the sun is in the zenith, are, respectively, 2.0, 4.0, and 6.0. The depletion of solar radiation of different wave lengths is expressed by the equation

$$I_\lambda = I'_{0\lambda} a_\lambda^m \tag{1}$$

where $I'_{0\lambda}$ is the intensity of radiation of wave length λ before it entered the atmosphere, a_λ the atmospheric transmission coefficient for the given wave length, and

Pyrheliometric readings made at the time the bolograms are obtained make it possible to express the radiation intensity they represent in absolute heat units, and the ratio of their areas, after making allowance for band absorptions, to the area of the bologram for zero atmosphere, make possible the determination of the intensity outside the atmosphere, I'_0, with considerable accuracy. Then for the solar constant

$$I_0 = I'_0 R^2, \tag{2}$$

where R is the earth's radius vector at the time the measurements were made, in terms of its mean value.

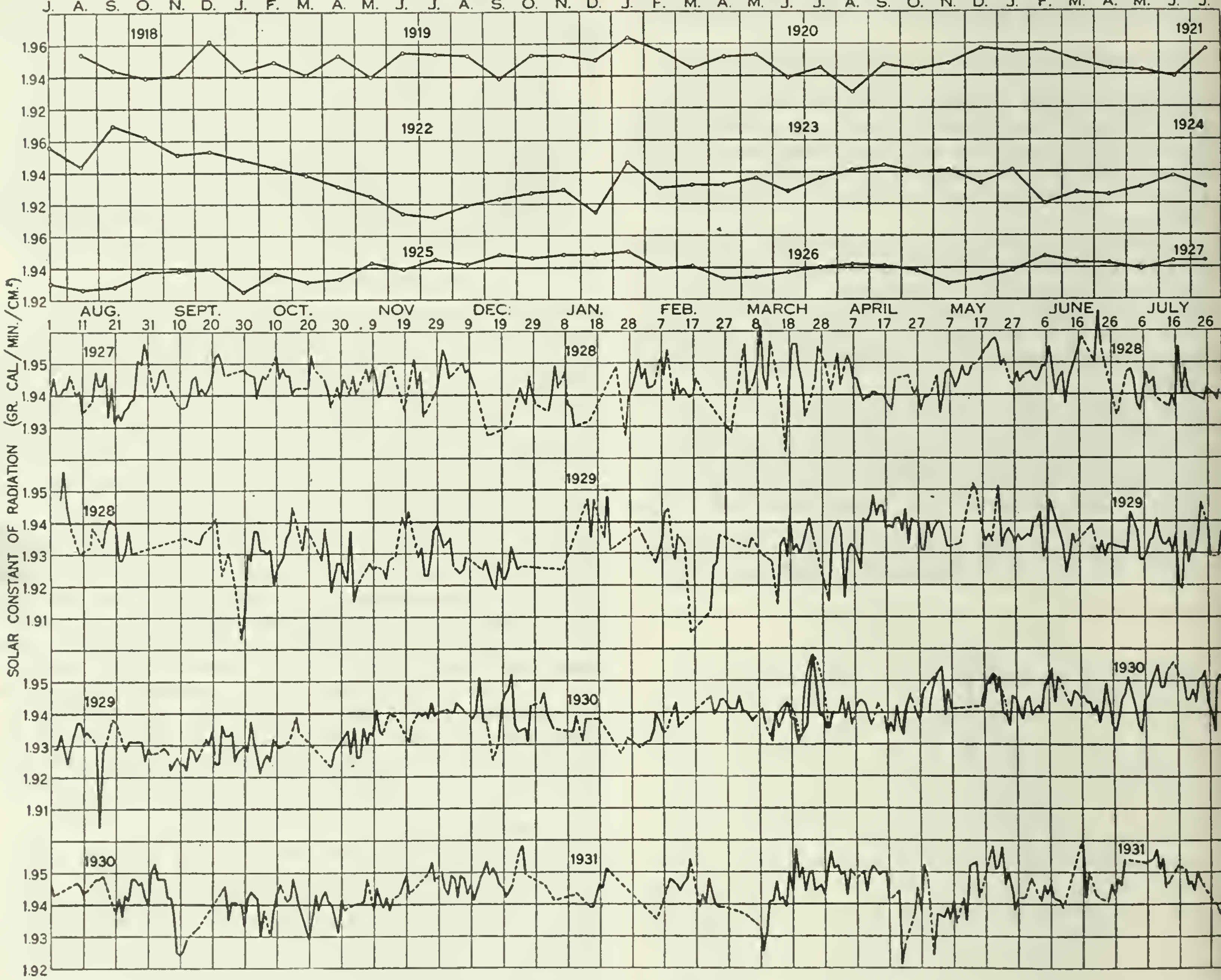

FIGURE 3.—Solar constant values

I_λ the measured intensity for the same wave length at the surface of the earth.

Equation (1) may also be written

$$\text{Log } I'_{0\lambda} = \log I_\lambda - m \log a_\lambda \tag{1'}$$

which is the equation of a straight line. Therefore, if the atmospheric transmission remains constant throughout a half-day period, from several bolometric records it will be possible to extrapolate values of I_λ to zero atmosphere, and thus to construct the spectrobologram for solar radiation outside the atmosphere.

During the years 1902 to 1907, inclusive, 44 determinations of the value of the solar constant were made at the Astrophysical Observatory of the Smithsonian Institution, in Washington (**5**). Seven of these were graded poor. Of the remaining 37 values the mean, expressed in gram calories per minute per square centimeter, is 1.968, the maximum 2.252, the minimum 1.814, giving a range of 0.438, or 22 per cent of the mean value. There seemed to be such strong evidence of marked changes in the value of the solar constant that the Smithsonian Institution established an observing station on Mount Wilson, Calif., where solar constant determinations were

made during the summer and fall months from 1905 to 1920, the year 1907 excepted, and at Bassour, Algeria, in 1911 and 1912. A few determinations were also made on Mount Whitney in 1909 and 1910, and at Hump Mountain in North Carolina in 1917–18. The mean of all values obtained to the end of 1920, those at Hump Mountain excepted, is 1.936 gram calories per minute per square centimeter, and the range is from 2.133 to 1.780, or 18 per cent (**6**).

Still impressed by the marked variations in the value of the solar constant, in July, 1918, the Smithsonian Institution established an observing station at Calama, Chile, where it was hoped that solar constant values could be determined throughout the year instead of during the summer and fall months only, as was the case at Mount Wilson. During the first year the fundamental method followed at Mount Wilson was employed. Considerable variations in the solar constant were found, the maximum value being 2.018, the minimum 1.865, giving a variation of about 8 per cent of the mean (**7**).

It was recognized by the Smithsonian Institution that it is a weakness of the spectrobolometric method of determining the value of the solar constant that it is necessary to assume that the atmospheric transmission does not change during the few hours in the morning or the afternoon required to obtain bolograms over a sufficient range of air mass values to permit of accurate extrapolation to zero atmosphere. This led to the development of a new method of determination (**8**), which is independent of changing atmospheric transmissibility, and which therefore enables determinations to be made on days when a clear sky early in the half-day period becomes bad later, or vice versa, as well as on continuously clear days.

Briefly, from a measurement of the brightness of the sky in a 15° zone about the sun, and a spectrobolometric determination of the absorption of solar radiation by water vapor and other gases of the atmosphere, a so-called function, F, is obtained, by means of which, in connection with empirically determined curves, the atmospheric transmission may be found for about 40 different wave lengths and the solar spectrum energy curve extrapolated to zero air mass.

A disadvantage of this method is that the curves correlating the function F with the transmissions a_λ require a long series of spectrobolometric observations for their determination. It has been used at Calama and Mount Montezuma, Chile, since the end of June, 1919. The earlier determinations have undergone several series of corrections, however, so that up to and including July, 1927, only monthly mean values are now available (**9**). The monthly means, and daily values since August 1, 1927, are plotted in Figure 3. These latter are kindly furnished the Weather Bureau each day for publication on the Washington edition of the Daily Weather Map.

The maximum of 1,007 daily determinations made on Mount Montezuma, Chile, during the latter period is 1.966 gr. cal. per minute per square centimeter, and the minimum is 1.903, giving a range of 0.063, or 3.2 per cent of the mean value, 1.940. Both the extreme values were rated $S-$ by the observer, signifying that the sky conditions at the time were not the best. These 1,007 determinations give a standard deviation of ± 0.00856. There is evidence of periodic variations, however, and if we confine our attention to 157 determinations made between November 12, 1929, and June 26, 1930, in which there is little evidence of such variation, the standard deviation is ± 0.00536 and the probable error a little less than ± 0.2 per cent. This is an exceedingly small error.

Recalling that the absolute value of the determination rests on the rate of change in temperature of the Smithsonian silver disk pyrheliometer when exposed to solar radiation, that the rate is only about 4° C. in 100 seconds, and is measured by a mercurial thermometer graduated on the stem to tenths of a degree, it is evident that these readings must be accurate to the tenth of a scale division, or to 0.01° C. This accuracy is obtained by reading two pyrheliometers on alternate minutes, which reduces the probable error by $1/\sqrt{2}$. However, small errors in the determinations of atmospheric transmissibility for the different wave lengths are bound to occur.

In a publication entitled "Weather dominated by solar changes" (Smithsonian Miscellaneous Collection, vol. 85, No. 1, Washington, 1931), Doctor Abbot sum-

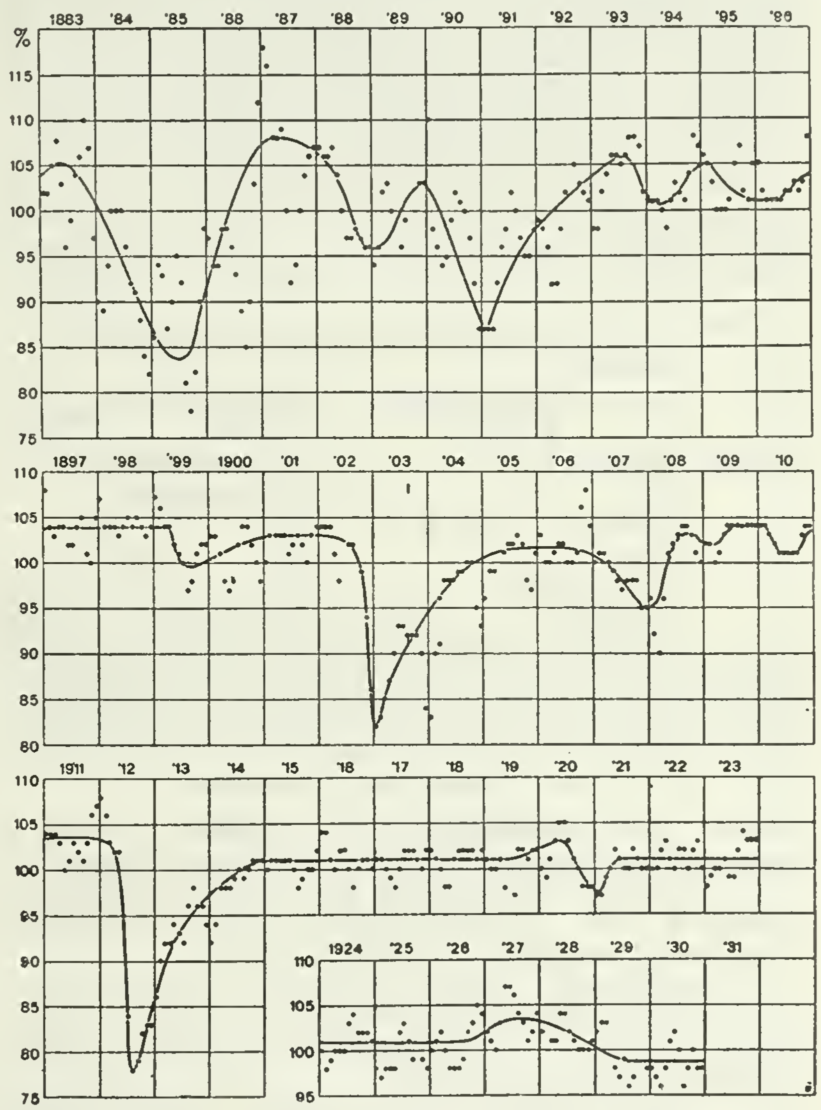

FIGURE 4.—Monthly averages of solar radiation intensity measured at the surface of the earth, expressed as percentages of the monthly normals

marizes the results of his studies of periodicities in solar constant values, basing his conclusions principally on the values obtained in the years 1924 to 1930, inclusive. He finds periodicities of 68, 45, 25, 11, and 8 months, respectively, in length, with amplitudes of from 0.3 to 0.7 per cent of the mean value, and projects them into the future to predict the trend of solar constant values to the end of 1932. The values actually obtained in 1931 are considerably lower, and have less range than was predicted.

In this publication Abbot states "I shall present evidence to show that weather * * * is caused chiefly by the frequent intervals of actual change in the emission of radiation within the sun itself." Then after discussing sequences of rising and falling solar radiation intensity, which he finds to occur in short intervals,

averaging five days, and in amount exceeding 0.4 per cent, and averaging 0.8 per cent of the value of the solar constant, he makes the further statement that "Major changes in weather are due to short-period changes in the sun." The reasoning by which this conclusion was reached is somewhat involved, and those interested are referred to the original paper for its elucidation.

Studies by forecasters and others at the United States Weather Bureau do not confirm the contention that "Major changes in weather are due to short-period changes in the sun."

VARIATIONS IN THE MEASURED INTENSITY OF SOLAR RADIATION RECEIVED AT THE SURFACE OF THE EARTH

In Figure 4 are shown monthly averages of solar radiation intensity based on measurements made at several different points in the Northern Hemisphere, and expressed as percentages of the normal intensities at the respective stations. In the earlier years systematic measurements are available from only one station, namely, Montpelier, France. In later years, measurements from as many as eight stations were available (**10**), but for the years since 1923 they are available to me from only four stations—Washington, D. C., Madison, Wis., and Lincoln, Nebr., in the United States, and Warsaw in

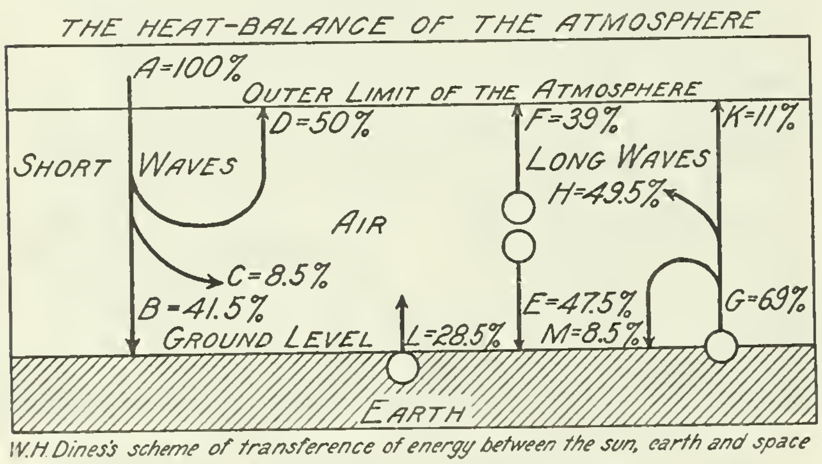

FIGURE 5.—The heat balance of the atmosphere

Poland. The measurements show marked periods of depression in the solar radiation intensity, as follows:

(1) In 1884–1886, following the eruption of Kratatoa Volcano in 1883. In 1885 the solar radiation was about 20 per cent lower than in 1883 and 1887.

(2) In 1888–1891, during a period of exceptional volcanic activity, but without any such outstanding eruption as that of Kratatoa. The decrease in intensity at the end of 1890 was about 15 per cent.

(3) In 1902–3, following the eruption of Pelée, Santa Maria, and Colima in 1902, with a sharp depression in solar radiation intensity at the end of 1902 of 20 per cent.

(4) In 1912–13, following the eruption of Katmai Volcano in June, 1912, which caused a decrease in solar radiation intensity in the following month of nearly 25 per cent.

The researches of Abbot (**11**), Humphreys (**12**) and others, indicate that these and earlier volcanic eruptions have been followed by a slight fall in the temperature of the earth as a whole, and especially at continental stations.

On the other hand, Ångström in a recent "Notiser" calls attention to the fact that since 1912, or for nearly 20 years, there have been no marked volcanic eruptions of an explosive character, such as throw great quantities of dust into the atmosphere. Therefore, the upper atmospheric layers, or the stratosphere, must now be unusually clear, and, in consequence, should deplete the incoming solar radiation less than usual. As a result the earth as a whole should experience a slight rise in temperature. This seems to be true of North America, while Europe has been cold and wet. Such apparent anomalies are not unusual, however, and are attributable to modifications in the atmospheric circulation.

It should be stated that of the radiation scattered from the direct rays of the sun by dust, perhaps one-half eventually finds its way to the earth's surface as diffuse radiation.

THE HEAT BALANCE OF THE ATMOSPHERE

In Volume III of his Manual of Meteorology, page 106, Figure 50, Sir Napier Shaw reproduces "W. H. Dine's (**13**) scheme of transfer of energy between the sun, the earth, and space," which is here shown in Figure 5.

	Per cent
(1) Short-wave, or solar radiation:	
A=solar radiation received at the outer limit of the atmosphere, $=1.94\times 1440\times \frac{\pi R^2}{4\pi R^2}=700$ gram calories per square centimeter per day	=100
D=amount returned to space by scattering and reflection	= 50
C=amount absorbed by the gases of the atmosphere	= 8.5
B=amount expended at the surface of the earth	= 41.5
$D+C+B$=total short-wave radiation accounted for	=100.0
(2) Long-wave, or low-temperature radiation:	
E=amount radiated to the earth by the atmosphere	= 47.5
M=amount scattered and reflected to the earth by the atmosphere	= 8.5
$[B]+E+M$=total radiation reaching the earth's surface	= 97.5
G=amount radiated from the earth's surface	= 69.0
L=amount transferred from earth to atmosphere through conduction and evaporation	= 28.5
$G+L$=total transmitted from earth to atmosphere	= 97.5
F=amount radiated from the atmosphere to space	= 39.0
K=amount transmitted through the atmosphere to space	= 11.0
$[D]+F+K$=total from atmosphere to space	=100.0
It is significant that of the total radiation reaching the surface of the earth $(B+E+M)$, B, short-wave radiation	= 41.5
And $E+M$, long-wave radiation	= 56.0
Also, of the total radiation expended in the atmosphere, $(C+L+H)$, C=short-wave radiation	= 8.5
And $L+H$, long-wave radiation	= 78.0

When we consider the secondary part played by the short-wave radiation in heating the atmosphere, and the many factors that enter into the determination of the relative values of D, C, and B, such as cloudiness, character of the ground cover (for example, dark or light colored soil, vegetation, sand, or snow), the water-vapor content and dust content of the atmosphere, etc., we may well question how a variation of less than 1 per cent in the value of A in a period of four to five days can have sufficient effect upon the value of either $M+E+B$ or upon $L+H+C$ to become apparent in the air temperature at a given place.

DAILY TOTALS OF SOLAR RADIATION RECEIVED AT THE SURFACE OF THE EARTH

In Figure 6, curve 1 shows for the entire year the daily totals of solar radiation received at the outer limit of the atmosphere for the latitude of Washington, 38° 56′ N. Broken lines show what would have been the daily totals in midsummer and in midwinter, had the earth been at its mean solar distance. Curve 2 gives the daily totals with clear skies measured at Twin Falls, Idaho, latitude

42° 29′ N., altitude about 4,300 feet, and curve 3 gives corresponding values for Washington, D. C., altitude about 400 feet.

Curve 4 gives the normal daily values with average skies at Twin Falls, curve 5 the corresponding values for Washington, and curve 6 summarizes measurements made by the weather bureau at the University of Chicago, latitude 41° 47′ N., altitude 688 feet.

On the normal values of curve 5 are superposed the weekly averages for Washington for the year 1925. These values show for the weeks centering on March 22 and 29 a variation at Washington from 111 to 56 per cent of the normal values, or 30 per cent of the amount received at the outer limit of the atmosphere. Daily values show on September 3 to 4, 1931, at Washington, a variation from 35 to 115 per cent of the normal value, or 41 per cent of the receipt at the outer limit of the atmosphere.

These daily and weekly variations in the total solar radiation received at the surface of the earth are due principally to the amount of clouds present in the atmosphere. Since extensive cloud areas usually accompany storms, considerable portions of a continent may at a given time be covered by clouds.

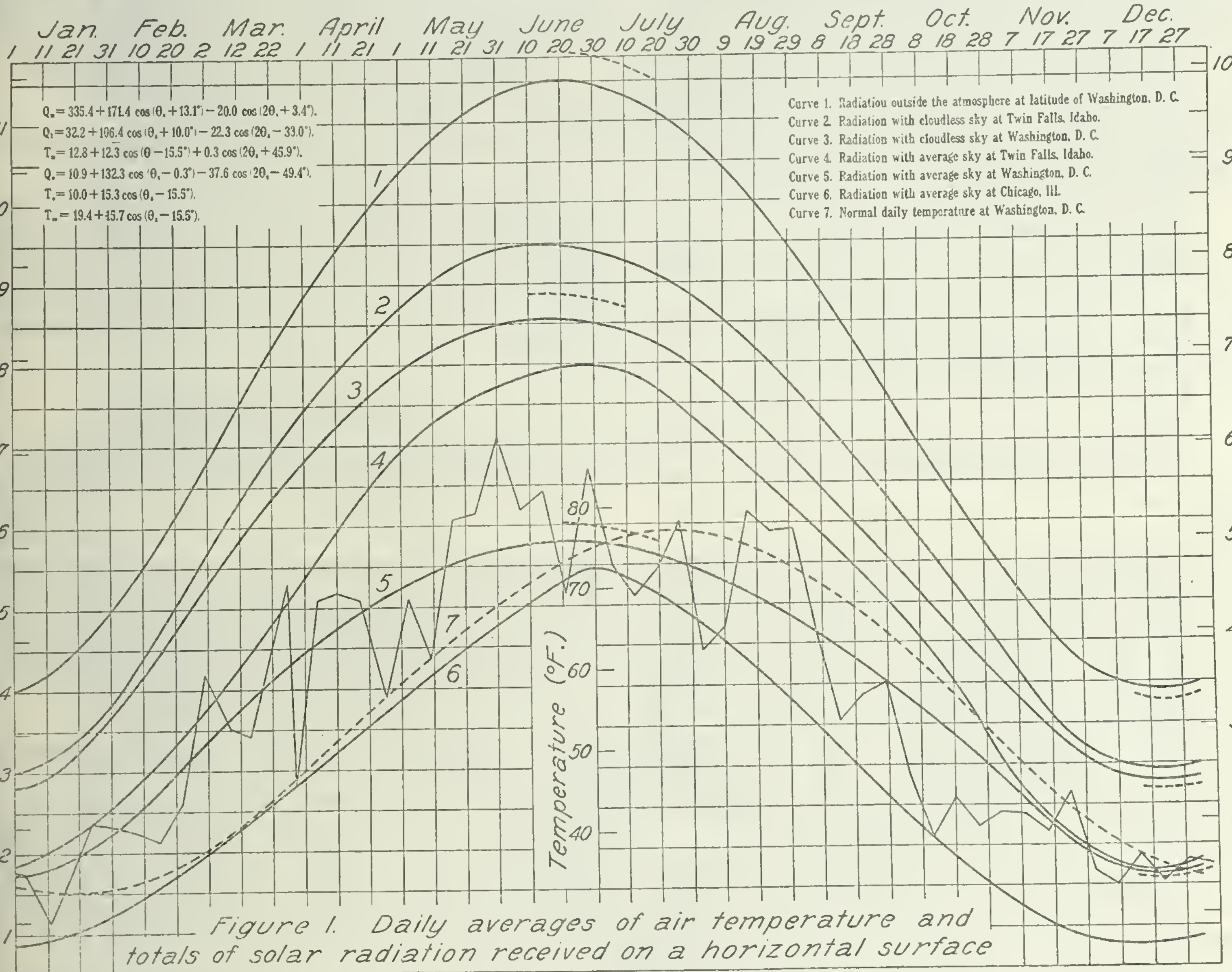

FIGURE 6.—Annual curves of daily totals of solar radiation

SOLAR ENERGY RECEIVED PER SQUARE MILE

It is interesting to note that on a cloudless day in midsummer at Twin Falls the daily receipt of solar energy per square mile of surface is equal to nearly 33,000,000 horsepower-hours, and at Washington to nearly 30,000,000. Also, on an average day in midsummer at Twin Falls the daily total is equal to about 27,000,000, and at Washington to 20,000,000 horsepower-hours. If it were possible to concentrate this energy as water power is concentrated, industry would have at its command an inexhaustible source of power.

RELATION BETWEEN INSOLATION AND AIR TEMPERATURE

The annual curves of daily totals of solar radiation and air temperature may be expressed by equations of the Fourier type (14). Thus, the equation for Q_m, Figure 6, represents curve 5, and that for T_m represents curve 7 (15). Also, we may compute the equation for Q_t the radiation available for heating the atmosphere after deducting from Q_m the loss due to reflection, the amount expended in evaporation, and the amount radiated to space. We may also compute Q_s, the radiation that should be available for heating the atmosphere if the ground were continuously covered with snow from December 1 to February 28, inclusive, and the resulting temperature curve represented by T_s. Likewise, from the equation for curve 3 we may compute the radiation and temperature curves Q_{oc} and T_{oc} for continuous sunshine at Washington.

The equation for T_s shows that with a continuous snow cover on the ground at Washington during the three winter months the midwinter temperatures would be 5° C.

colder than with an average snow cover, due to the greater loss of radiation through reflection, which accords with observations. With no snow on the ground zero temperature Fahrenheit has never been recorded at Washington, while with a snow cover a temperature of − 15° F. has been recorded.

Similarly, with continuous sunshine the equation for T_{oc} gives midsummer temperatures 11° C. or 20° F.,

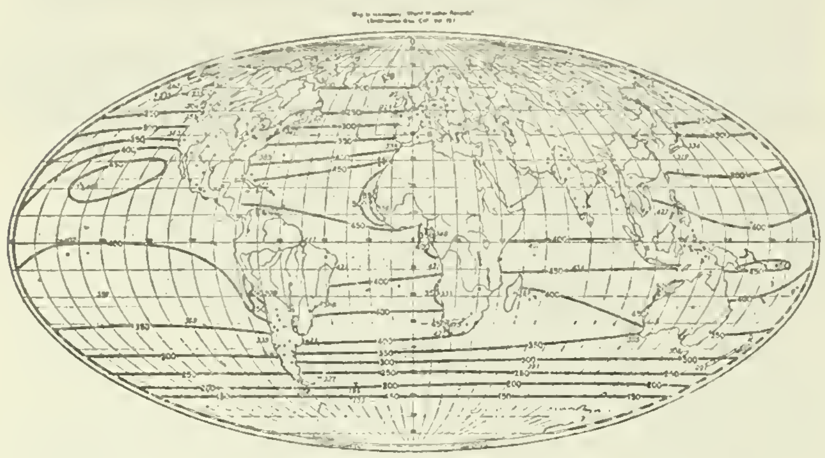

FIGURE 7.—Isopleths of the total solar radiation (direct + diffuse) received on March 21, with average cloudiness (Gr. cal. per day per sq. cm.)

warmer than at present, giving daily means of 96° F., or temperatures representing desert conditions.

In the above equations, $\theta_x = 0$ on July 5.

SOLAR RADIATION AS THE SOURCE OF WEATHER AND CLIMATE ON THE EARTH

Such observations as are available do not indicate that variations in the value of the so-called solar constant of radiation, or in the depletion of radiation by changes in the atmospheric transparency have produced marked effects upon the temperature of a given place, or of the world as a whole. However, C. E. P. Brooks, in Climate Through the Ages, after reviewing the effect of volcanic dust upon the pressure distribution as well as upon atmospheric temperature, and especially the weakening of the southwest wind over the Atlantic Ocean and western Europe due to the marked decrease in the pressure gradient between the Azores and Iceland following volcanic eruptions, concludes that volcanic dust may explain climatic periods colder than the present.

Attention is invited to the fact that in the equation for Q_T, the annual term is plus, indicating a surplus of radiation over what is required to maintain the annual temperature T_m. Ångström found for Stockholm, that the annual term in the equation for Q_T is minus. It would seem, therefore, that a transfer of the excess of heat in low latitudes is necessary to make up the deficit in high latitudes.

It is difficult to chart daily average values of insolation over the continents for the reason that altitude above sea level is an important factor in determining these values. Only a few radiation measurements have been made at sea, but if we know the average cloudiness, the average water-vapor content and dust content of the atmosphere over the ocean, we may compute the corresponding average solar radiation intensity for a given day at given latitudes with reasonable accuracy. This I have done, using such records of cloudiness, air temperature, and relative humidity for marine stations as are available (16). The results for average cloudy conditions are shown in Figure 7 at the time of the vernal equinox, in Figure 8, at the time of the summer solstice, and in Figure 9 at the time of the winter solstice. They check satisfactorily with such measurements as have been made.

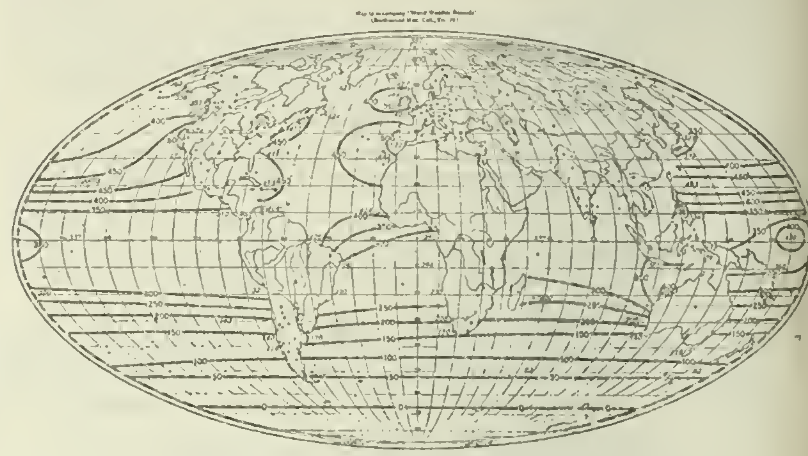

FIGURE 8.—Isopleths of the total solar radiation (direct + diffuse) received on June 21, with average cloudiness (Gr. cal. per day per su. cm.)

Note the decrease with latitude in the daily totals of solar radiation, which is particularly marked at the time of the winter solstice. As is well known, there results a corresponding decrease in temperature in winter from 70° F. at the equator to −37° F. in the vicinity of the North Pole, and to −51° F. in Siberia, or temperature differences of 107° to 121° F.

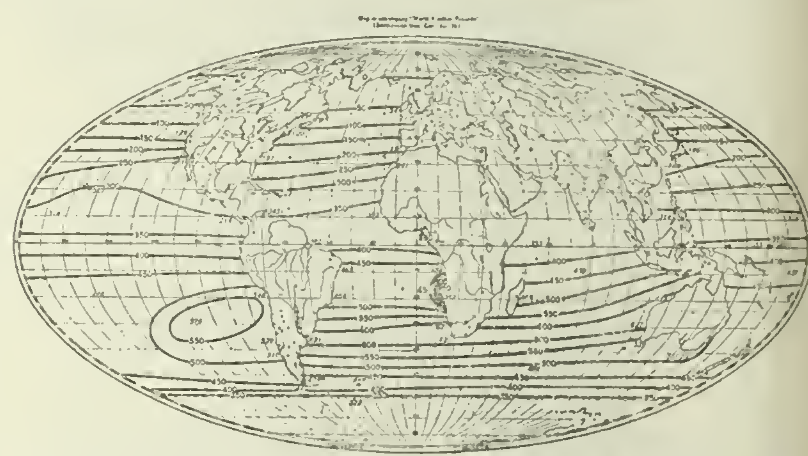

FIGURE 9.—Isopleths of the total solar radiation (direct + diffuse) received on December 21, with average cloudiness (Gr. cal. per day per sq. cm.)

In July the temperature differences are much less. At the equator, over the oceans, the mean temperature is still about 70° F., but over the interior of continents it is 90° F., while at the North Pole it is about 35° F., giving temperature differences over the ocean of only 35°, and from continents to the North Pole of 55° F.

THE POLAR-EQUATORIAL EXCHANGE OF AIR MASSES

When two bodies of air of unequal temperatures lie near each other, gravity causes the cold air to displace the warm air at the earth's surface. In this way atmospheric circulation is initiated, which on a nonrotating globe of uniform surface, might be quite regular. On a rotating globe with an irregular surface like the earth, consisting partly of land and partly of water, and the land surfaces not planes, but mountain peaks and mountain chains separated by deep valleys, the circulation of the air is bound to be turbulent. It is this turbulent interchange of air between the warm and the cold regions on the earth's surface that generates storms and the various phases of weather that accompany them.

Figures 10, 11, 12, and 13 give an illustration of these air movements over the United States and the accompanying weather changes. On the morning of January

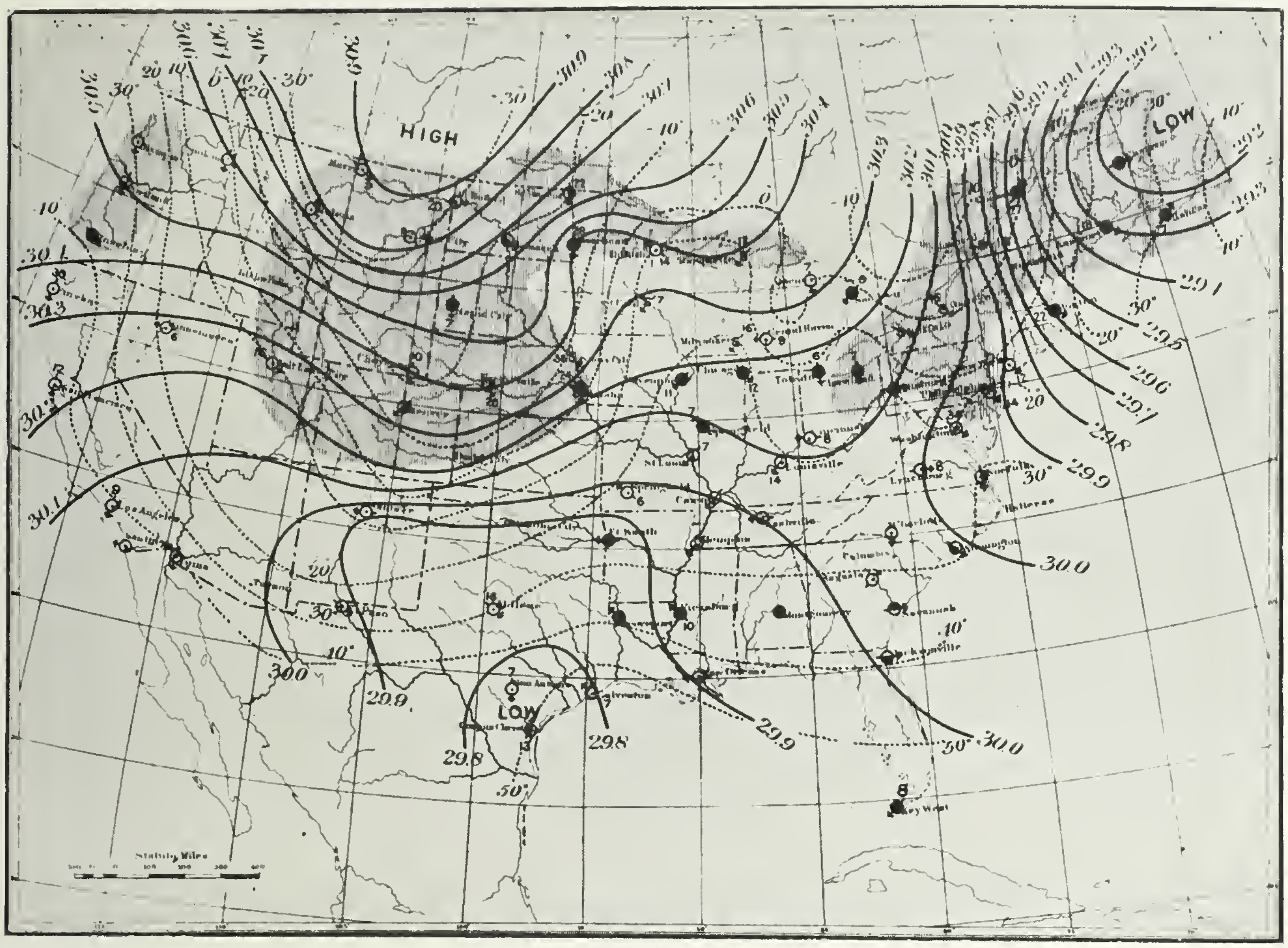

FIGURE 10.—Weather map of the United States for 7 a. m., January 7, 1886

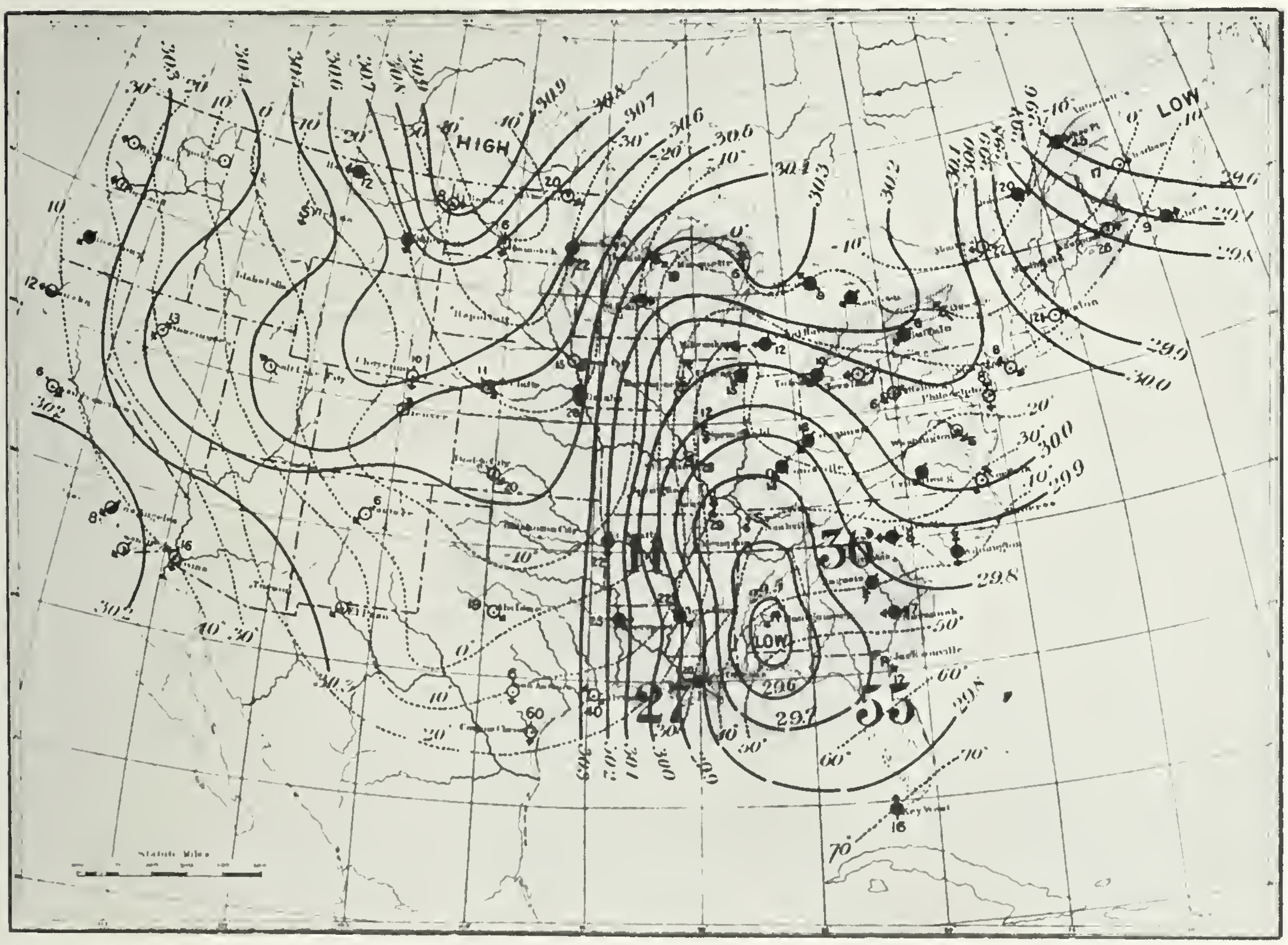

FIGURE 11.—Weather map of the United States for 7 a. m., January 8, 1886

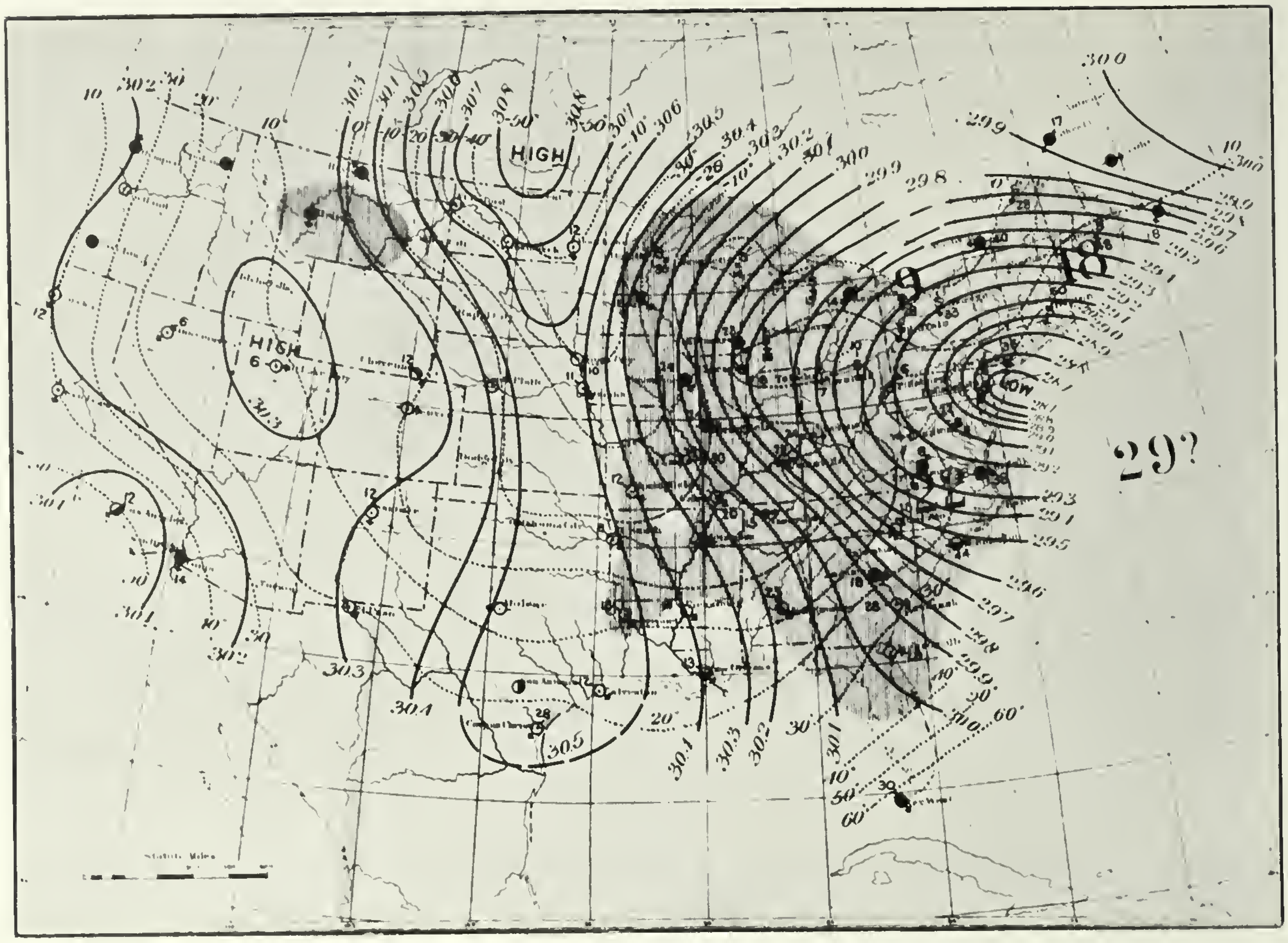

FIGURE 12.—Weather map of the United States for 7 a. m., January 9, 1886

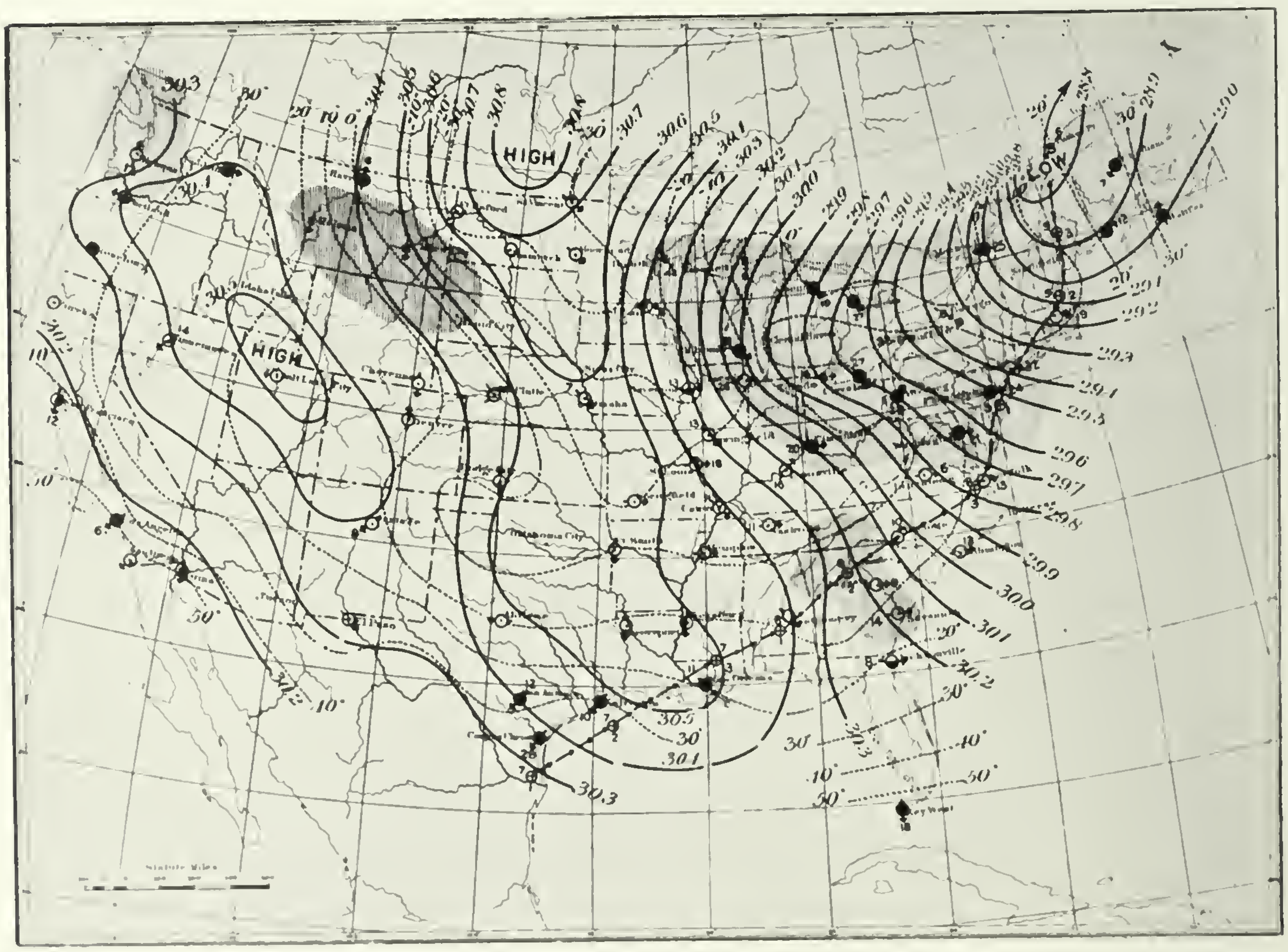

FIGURE 13.—Weather map of the United States for 7 a. m., January 10, 1886

1886, a low-pressure area was passing off the North [A]merican coast near the mouth of the St. Lawrence River. [W]arm south to southwest winds prevailed on its front, [an]d cold winds, generally from the northwest, on its [r]ear. A high-pressure area was overspreading the [R]ocky Mountain Plateau with winds generally from the [n]orth and with temperatures as low as 30° below zero. [T]here were indications that a cyclone was developing [o]n the Texas coast, with winds in the lower Mississippi [V]alley from the southeast.

In the July, 1931, number of the MONTHLY WEATHER [R]EVIEW, Bjorkdal (17) defines *frontal zones* and *fronts*, [a]s follows:

When two air masses each uniformly homeogeneous approach [e]ach other nearer than about 1,000 kilometers (620 miles), the [a]rea between them no longer fulfills the conditions of a homeo[g]eneous air mass. A *frontal zone* occurs which can gradually [sh]arpen to a *front*. Fronts are narrow inclined transition zones [o]f the same vertical extent as the air masses. It is essential that [t]he difference of the values on both sides of the front of at least [o]ne of the independent elements (temperature, pressure, wind, [h]umidity) is so great that it has an appreciable effect on the great-[s]cale dynamics (of the air mass).

Evidently on the morning of January 7, a *frontal zone* [e]xtended from the Texas coast northeastward to Illinois, [a]s shown by the wind directions and temperature lines. [O]n the morning of the 8th, it had sharpened into a *front* [w]hich extended northward from near the mouth of the [M]ississippi to Lake Michigan having a 20° rise in tem[p]erature in 24 hours with the south winds to the east [a]nd a 30° fall in temperature with the north winds to [t]he west. Large figures show the average temperature [i]n each quadrant of the cyclone.

Note on the 9th the marked development of the low [c]enter on this polar front, and its movement toward [t]he northeast. The flow of cold air from the north now [c]overs practically the whole country east of the Rockies, [e]xcept the extreme northeastern section. The map for [J]anuary 10 shows temperatures as low in Florida as in [N]ew Brunswick, Canada, near the mouth of the St. [L]awrence River.

Cyclonic storms of this type often persist for days, [c]rossing oceans from continent to continent, and in rare [c]ases completing the circuit of the globe.

The above are only instances of great major changes which are continually going on in weather conditions all over the earth; although during the spring months, as the temperature difference between the equator and the pole diminishes, the extent and the intensity of the air movements also diminish, and become comparatively weak in summer, just when the effect of solar variability should be at its maximum. Therefore, is it rational to believe that these major weather changes are caused and explained by alleged short-period changes of less than 1 per cent in the intensity of solar radiation? A part if not all of this 1 per cent variation must be set off as caused by inevitable accidental errors, but even if the whole of it were real solar change, can we believe that if this small variation were to cease our major weather changes would disappear also?

The importance attributed by meteorologists to the polar-equatorial exchange of air is attested by the program adopted by the International Meteorological Committee for the Jubilee Polar Year, 1932–33. It is proposed to surround the North Pole with stations so completely equipped and manned that it will be possible to publish hourly values of the principal meteorological elements. It is also proposed to reproduce all automatic records obtained. Those from polar stations should show the origin of polar fronts, and those from stations in lower latitudes, their progress. Meteorological observations will not be confined to low-level stations, but upper air conditions will be recorded, at mountain stations, and by means of balloons, kites, and airplanes at numerous aerological stations. Also, especial attention is to be given to observations of the aurora, by eye observations, by synchronous photographs at neighboring stations to determine auroral heights, and by spectroscopic observations, with a view to learning more about atmospheric conditions at great heights.

As stated by the chairman of the commission for the polar year (18).

The further that extensions have been made of the dynamical theories of air interaction in moderate latitudes for practical forecasting purposes, the clearer has it become that atmospheric processes in the polar regions of both hemispheres play a predominant part. These regions are very often the source of the surges in the atmosphere whose necessary outcome are the weather variations at low latitudes. An intimate study, therefore, of the behavior of the atmosphere in high latitudes has now become a necessity for the extension in knowledge of weather processes.

It is from studies of this character that meteorologists are attempting to increase their knowledge of the generation and movements of storms and of the weather changes that accompany them.

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INTERNATIONAL MEETINGS IN SEPTEMBER AND OCTOBER, 1931

By C. F. BROOKS

Three recent international meetings of interest to meteorologists generally were the International Geographical Congress in Paris, the meetings of three commissions of the International Meteorological Organization in Innsbruck, and the joint meeting of the German and Austrian meteorological societies in Vienna. At the Paris congress, local climates and changes of climate in historic times were discussed at some length. The occurrence of marked contrasts in climate, especially temperature, in surprisingly short distances, was emphasized. A study of the different economic effects of contrasted climates in modern times was urged as a basis for interpreting the human record of earlier centuries in terms of climate. Certain changes in Egypt in the past 2,000 years are ascribable to factors other than climate, and it was concluded that the climate of Egypt has not changed appreciably since the time of Christ. This tallies with similar investigations made in Palestine and in Greece.

The meetings in Innsbruck comprised the Climatological, the Terrestrial Magnetism and Atmospheric Electricity and the Polar Year commissions. The city, the university, and the Tirolean government officials were unstinting in their entertainment of the small group of meteorologists assembled for these meetings. There were complimentary dinners and excursions to the mountains near by. The snow and cold weather of the first four days made the last two only the more beautiful.

Though this was the first meeting of the Climatological Commission, Dr. H. von Ficker, the president, guided its labors so effectively and Dr. W. Knoch, the secretary, prepared such excellent minutes, that a large program was put through without haste, yet within the limits of the seven sessions originally scheduled. Chief attention was directed toward bringing climatological programs into step with modern synoptic programs, both as to hours of observation and publication of daily values. Radio broadcasting of monthly means for a selected network of stations over the earth was recommended in order to aid studies in world weather and to make possible some long-range forecasting based on knowledge already gained. Studies in dynamic climatology, particularly of the frequency of occurrence of different air bodies (e. g., polar air and tropical air) and of the frequency of passage of fronts should be made at selected stations. Furthermore, the commission believed that daily weather maps of the northern hemisphere were much to be desired.

The Commission on Terrestrial Magnetism and Atmospheric Electricity and the Polar Year Commission under the able leadership of Dr. P. La Cour greatly advanced the project for the International Polar Year, 1932–33. On account of the world-wide economic depression the question was raised as to whether the plan for the polar year should be pressed forward or deferred until a more auspicious time. Those members of the commission who were present unanimously favored continuing the polar year plan, so great was the current interest, and so hopeful were they that notable results would be obtained. The networks of stations were recommended in detail, their programs were outlined including photographic observations of the aurora, and detailed cloud and aerological observations. Radio sounding balloon work for certain stations was specially recommended, and the need for mountain observatories stressed. Plans were laid for observations during the total solar eclipse of August 31, 1932. The cooperation of observatories all over the world was solicited, especially on international days.

High spots of the meeting of the Austrian and German meteorological societies in Vienna were, the unveiling of the bronze placque of Julius von Hann in the hallway of the Zentralanstalt für Meteorologie und Geophysik, Dr. P. Goetz's photographs of sun pillars, and the symposium and exhibit on microclimatology arranged by Dr. W. Schmidt. This symposium disclosed a considerable activity in local climatology in central Europe, especially Vienna. Members of the staff of the Zentralanstalt had not only made temperature surveys and profiles through day and night, but also while traveling by auto investigated instrumentally the influence of the city on solar radiation. The reduction of sunlight intensity by city smoke in Vienna was shown to be very great, of the order of 50 per cent. After the symposium a room full of apparatus and maps and diagrams dealing with microclimatology was thrown open to inspection. Stationary and traveling instruments and observers have been used effectively in microclimatological investigations. The use of the automobile specially equipped with a psychrometer and other apparatus, is increasing rapidly. Knowledge of local differences in climate is valuable both economically and meteorologically. Farmers, orchardists, even city dwellers, are interested in a very practical way. The meteorologist sees in local differences convenient samples of equal differences in general climate at places separated by 500 to 1,000 miles.

The papers of the Paris Congress will soon be published in the proceedings of the Congress. The transactions of the several international commissions will be published by the secretariat of the International Meteorological Organization, and the papers presented at the Vienna meeting will be published in full or in abstract in the Meteorologische Zeitschrift.

LOCARNO MEETING OF THE METEOROLOGICAL COMMITTEE, OCTOBER, 1931

By C. F. Marvin

During the first week of October, 1931, meetings were ld at Locarno, Switzerland, of the International eteorological Committee, under the chairmanship of r. Van Everdingen, including a meeting of the council d of the subcommission organization of meteorological ports over the oceans, under the chairmanship of Genal Delcambre. The Chief of the U. S. Weather Bureau a member of each of these groups, and attended the eetings in person.

The matter of first importance in connection with the eeting at Locarno was the fact that the so-called execuve council, consisting of representatives of five nations, e of these representatives being the president of the ternational Meteorological Organization, held its first eeting after it was created at the conference of directors Copenhagen, in 1929. This was, therefore, its organition meeting. In addition to deciding upon necessary les and regulations for accomplishing the work of the uncil, decisions were reached in regard to the budget d funds for the maintenance of the office of the secreriat during the forthcoming year, and the projects ntatively under way were approved. With some modiations these rules and regulations were subsequently proved by the International Meteorological Comittee, and they have now become the permanent guide r this new feature of the work of the International eteorological Organization.

The major part of the sessions of the committee was evoted to the reading of reports by the president of the pper Air Commission, which held its meeting in Madrid cently, and the president of the Polar Year Commission, llowing the meeting of that and some other commissions Innsbruck, Austria, in September. The committee evoted considerable time to discussion of the numerous resolutions that resulted from the reports mentioned, and these resolutions, with such modifications as were deemed necessary, were approved or indorsed by the International Committee.

Also meetings were held of the subcommission on organization of the meteorological work of the oceans, more particularly with reference to the ship report work from selected ships on the North Atlantic. Some of the difficulties in connection with the reception and distribution of reports were discussed, and agreements were reached with a view to realizing more uniform and better and more valuable service in the future.

Almost coincidentally with the meetings at Locarno, in connection with ship reports from the oceans, an international conference of radiomarine organizations was held in New York, at which particular consideration was given to the agreement between all radio organizations to transmit meteorological reports from ships at sea free of cost for what is called the "ship tax," in view of the important benefits that navigation, including radio interests, receive from the free dissemination by meteorological services of forecasts, warnings, and important meteorological information.

Perhaps one of the most important actions taken at the Locarno meeting was the decision that, notwithstanding the difficulty confronting the various nations at the present time, the program of intensive observational work which had been previously planned and provided for by nearly all nations for the so-called polar year, beginning with August, 1932, and extending to August, 19, 1933, should be carried through, although it was recognized that the critical situation might make it impracticable to carry out all the features of the program originally contemplated.

WHITE LIGHTNING VERSUS RED AS A FIRE HAZARD

By W. J. Humphreys

Mr. Seley W. Moore, of Darby, Mont., says, in a letter ated October 14, 1931, that he spent the summers of both 930 and 1931 on a lookout, that is, a place commanding wide view from which watch is kept for forest fires, and hat it was his observation that red lightning, though ften tearing trees to pieces, seldom starts a fire. Now, t is well known that many forest fires are started by ightning, especially by that of "dry" thunderstorms—he thunderstorms whose rain, being all evaporated in id-air, does not reach the earth. We therefore infer hat if it be generally true that red lightning seldom starts fire then the lightning of a dry thunderstorm must not e red. Indeed since in this case those portions of the lectric discharges which are clearly seen occur out in he open and rainless air their light must be owing almost ntirely to the two gases oxygen and nitrogen, and thereore contain too little red for that color to become conpicuous even when the lightning is a long ways off. Essentially it is white lightning or even bluish white. On the other hand, a lightning discharge through heavy rain may well dissociate some of the water, or water vapor, along its path, and thereby produce also the hydrogen spectrum, which is brilliantly red, in addition to those of the chief gases of the atmosphere, oxygen and nitrogen. In this way the lightning would, and doubtless does, become distinctly red. Apparently, then, lightning through rain is, or may be, red while that through the air where there is no rain is not red, but commonly white. Hence red lightning, being through rain, strikes only wet objects and therefore seldom starts a fire, while white lightning may, and often does, strike dry fuel which is far more easily fired than is the same sort of duff or other material when wet. In short it is not the difference between white lightning and red lightning that makes the one a greater fire hazard than the other, but the condition, wet or dry, of the combustible when struck.

SEVERAL CLOUD SPOUTS

By EDWARD M. BROOKS (Worcester, Mass.)

Several cloud spouts were recently observed from the open east slope of Mann Hill, Littleton, N. H. (lat. 44° 21′ N., long. 71° 44′ W., altitude 1,475 feet above sea level). These cloud spouts were interesting because they occurred at an unusual place and times of day; they were moving in uncommon directions; and, even though one looked like a tornado, it caused no apparent damage.

At 7:30 p. m. (E. S. T.) on July 9, 1931, while the air was calm and sultry, a dark cloud approached at a moderate speed from the north-northwest. A quarter of an hour later, a sudden breeze came over the hill from the northwest just after the front of the dense cloud had passed overhead. Suddenly at 7:50 p. m. a cloud like a puff of smoke rose at a rapid rate from a near-by valley in the southeast. But as this arose, more cloud formed below and so on until there was a ragged column of cloud between the ground and the base of the dark cloud above. This column soon became weaker as it moved southeastward. However, there were other patches below the general cloud base and ragged cones hanging half way down to the ground in the immediate vicinity; one of these, about 5 miles north of the main spout, developed into a rough column extending nearly to the ground. Some of these patches and cones converged with it, especially from the southwest, at the rate of about 35 miles per hour. By this time, 7:55 p. m., the mass, which was now a tornado cloud in the form of a dense funnel-shaped cone inside a rough cylinder of thinner cloud, had receded toward the southeast over the slope of a hill (elevation 1,200 feet above sea level). Since the elevation of the cloud base was about 2,000 feet above sea level as indicated by an observation made with a psychrometer immediately afterward, the tornado cloud was about 800 feet in height. By estimation, a certain portion of a cloud required 25 or 30 seconds to ascend from the ground to the cloud base. Hence the rate of ascent was about 30 ft./sec.

When it was at its best, the cloud spout had reached a point 1½ miles northeast of Wing Road (lat. 44° 19′ N., long. 71° 39′ W.). At 8:00 p. m. it had passed over the little hill into a swamp on its southeast side. But by this time the cone had broadened, become less dense, and merged with the huge cylinder, thus indicating a decrease in intensity of the whirl. At 8:05 p. m. the lower end of the column had risen from the ground and was half way to the cloud base. As the cloud spout approached Beech Hill a few minutes later, it disappeared. Except for a few scattered trees probably blown over by it, no damage was visible from the highway running northeastward from Wing Road.

During the night the northerly wind continued, but with much reduced velocity, and heavy rain fell, ceasing on the morning of July 10. At 7:45 a. m. the sky was mostly covered with dense strato-cumulus clouds moving generally from the southwest. Also there was some fog in a few valleys, especially to the southeast, but it was moving slowly from the north or northeast. At 7:55 a. m. there were a few low clouds about 8 miles to the south-southeast of us in front of Mount Garfield. At 8:00 a. m. these clouds were rising into the cloud base and soon a cloud spout had formed. The rate of ascent of cloud projections from the side of the spout was about 25 ft./sec., according to a rough angular measurement by C. F. Brooks. The spout at its best probably extended to the ground, but this is not certain since Mount Agassiz and Cleveland in Bethlehem cut out half the view. It did not last long because its top was moving in the opposite direction from its base, thus causing it to lean at the top toward the northeast and finally to separate. Other cloud spouts kept forming between 8:00 and 8:30 a. m. in various places toward the southeast, but they were weaker than those that preceded.

A TORNADO CLOUD IN THE FREE AIR

By ALFRED C. HAWKINS

A very unusual tornado cloud was observed by many people at Wilmington, Del., September 4, 1931. It was a fine summer day, with blue sky, and about 0.2 cirrus and 0.4 cumulus, the latter in small detached showers, high but only a few miles broad. Surface wind from the west, about 5 miles per hour, and cumulus in upper part moving very slowly from the west; lower dark, ragged nimbus from the west-southwest.

The largest shower was due east of Wilmington, I should judge 15 or 20 miles east of the Delaware River, over New Jersey. It was building up and backward and did not appear to move. At 5:45 p. m. a narrow white ribbon appeared in the sunlight, joining the upper part of the cumulus with a nimbus layer at the bottom. It looked like the white ribbon of smoke which an airplane laying a smoke screen might make on a long vertical dive. From 5:45 until 6:00 p. m. this tornado spout was visible, retaining the same position, but developing a bend about two-thirds of the way down, and finally fading out at the bottom, developing a thin point which ascended and descended at intervals. A bulge formed in the spout at times and traveled downward toward the bottom. We could see the spout revolving, but it was never wide at the top. At times the bottom of it glowed a beautiful rose color in the sunlight. It never reached anywhere near the ground, but simply joined the two layers of cloud. If the bottom of the cloud at the dew point were about a mile above the earth, then the spout must have been approximately half a mile high. At 6:00 p. m. some dark nimbus clouds came along and obscured the spout, although it could be seen for some time through holes in the nearer clouds.

PRELIMINARY STATEMENT OF TORNADOES IN THE UNITED STATES DURING 1931

By Herbert C. Hunter

(Weather Bureau, Washington, February 2, 1932)

In advance of the final study of windstorms of 1931, which probably will be finished during next summer, and in accordance with the practice of recent years, a preliminary statement is made in the December issue of the Review of the results derived from information secured through the assistance of many observers, especially the several sections directors. Practically all this material has been employed in compiling the monthly tables of "Severe Local Storms."

The number of tornadoes and the damage they caused were considerably less than for any other recent year, and it is especially gratifying that the loss of life was less than half the least in any of the preceding 15 years. The greatest loss of any month was in December although this usually is the season of least tornado activity.

TORNADOES AND PROBABLE TORNADOES

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Number	3	0	5	2	12	20	11	11	12	4	4	5	89
Deaths	7	----	3	0	2	2	0	1	5	0	0	14	34
Damage [1]	48	----	115	6	272	215	39	135	828	80	16	72	1,826

TORNADIC WINDS AND POSSIBLE TORNADOES [2]

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Number	0	0	0	1	0	1	0	0	1	0	0	0	3
Deaths	----	----	----	0	----	0	----	----	0	----	----	----	0
Damage [1]	----	----	----	2	----	25	----	----	3	----	----	----	30

[1] In thousands of dollars.
[2] Some of these, in the final study, may be classed as not tornadoes.

THE WEATHER OF 1931 IN THE UNITED STATES

By Herbert C. Hunter

The year was marked by unusual warmth over the greater part of the country, and was somewhat warmer than normal in all but a very few small areas. Temperatures were particularly above normal in the months usually styled the winter months—December, January, and February—also considerably in the autumn months and July.

Of the 12 months only March averaged cooler than normal, on the basis of the district departures shown in Table 1, although May was practically normal in the country as a whole.

The accompanying temperature-departure chart, like the right-hand column of Table 1, indicates that the north-central portion of the country had the greatest positive departure for the year as a whole, as it also had in 1930, 1928, and 1921. In general, 1931 and 1921 were the warmest years experienced in the United States during a considerable period.

The smallest departures were found in the Florida Peninsula and the Southern Slope. Indeed, the former averaged more than half a degree below normal temperature during the 11-month period, January to November, but the warmest December of record succeeded, making the district temperature average for the entire year slightly above normal.

The precipitation was deficient in the country as a whole, but to a considerably less extent than in 1930. Once more the Florida Peninsula shows the largest excess for the year, but a considerably smaller excess than for 1930. The Southwest recorded more precipitation than normal, particularly the South Pacific district. The Middle Atlantic, Ohio Valley, and North Pacific districts, where 1930 saw marked deficiencies, experienced deficiencies also in 1931, as a whole; but shortages were less, particularly in the Ohio Valley and the North Pacific areas; also the distribution from month to month was not so unfavorable.

The South Atlantic district had a considerable shortage, notably during the 6-month period, June to November. The Northern Slope and North Dakota had marked deficiencies of rainfall starting in April and lasting through substantially all the months of the growing season.

During every month several districts received greater precipitation than normal and several others less than normal. As Table 2 indicates, the month of June had the greatest deficiency over the country as a whole, though February and May likewise fell short to a considerable extent. December alone showed an excess more than very slight, when all the districts were averaged.

It should be remarked that the two charts and the tables are based on reports from about 200 Weather Bureau stations and that a larger number and better distribution of the reporting stations would probably give a somewhat different result, especially as to the areas of positive and negative departures.

TABLE 1.—*Monthly and annual temperature departures, 1931*

District	January	February	March	April	May	June	July	August	September	October	November	December	Average
New England	+1.1	+1.7	+3.6	+2.7	+1.6	+0.8	+2.0	+1.4	+3.4	+3.7	+6.4	+3.7	+2.7
Middle Atlantic	+2.5	+2.9	−0.7	+0.1	+0.1	+0.6	+2.9	+0.7	+5.1	+3.4	+7.7	+7.2	+2.7
South Atlantic	+0.5	+1.1	−4.1	−1.4	−1.7	+0.9	+2.7	+0.1	+4.1	+2.8	+6.5	+8.5	+1.7
Florida Peninsula	−3.1	−1.8	−5.4	−1.8	−0.1	+0.5	+1.6	+0.9	+0.4	+0.9	+1.7	+8.3	+0.2
East Gulf	−0.4	+1.1	−5.4	−1.9	−2.8	+1.7	+1.4	−1.2	+4.1	+3.5	+6.8	+8.2	+1.3
West Gulf	+2.2	+3.7	−5.5	−3.9	−3.6	+0.9	+0.6	−1.2	+4.5	+5.9	+6.5	+3.0	+1.1
Ohio Valley and Tennessee	+3.0	+4.3	−4.3	−0.1	−2.7	+2.0	+3.1	−0.4	+5.2	+3.3	+9.0	+8.4	+1.3
Lower Lakes	+2.6	+4.4	+1.2	+1.8	0.0	+0.9	+4.0	+1.7	+5.5	+4.2	+9.1	+6.7	+3.5
Upper Lakes	+6.4	+9.6	+2.2	+2.1	−0.5	+3.1	+4.2	+1.7	+6.1	+5.4	+8.7	+8.1	+4.8
North Dakota	+16.4	+20.4	+3.7	+3.8	−0.5	+5.5	+2.6	+1.5	+5.1	+4.6	+3.9	+9.1	+6.3
Upper Mississippi Valley	+9.4	+11.6	−0.3	+2.3	−3.0	+5.3	+3.8	+0.7	+6.9	+5.3	+9.2	+10.3	+5.1
Missouri Valley	+11.1	+12.8	−1.1	+1.7	−2.5	+6.7	+3.6	+0.8	+7.5	+4.6	+5.3	+7.8	+4.9
Northern Slope	+10.1	+11.0	+1.2	+1.5	+0.9	+5.5	+3.2	+2.6	+3.4	+2.8	−2.4	+1.1	+3.4
Middle Slope	+6.8	+8.2	−4.0	−1.0	−2.6	+4.9	+2.6	−0.1	+7.9	+4.7	+1.8	+5.6	+2.9
Southern Slope	+1.7	+3.8	−5.4	−4.1	−3.9	+1.6	0.0	−0.6	+6.4	+5.5	+2.7	−0.1	+0.6
Southern Plateau	+1.4	+2.4	+1.2	+3.1	+2.8	+1.4	+3.9	+0.8	+2.2	+2.9	−1.9	−2.6	+1.5
Middle Plateau	+0.2	+3.6	+0.2	+2.3	+3.3	+3.9	+6.1	+3.5	+1.0	+3.8	−4.3	−5.1	+1.5
Northern Plateau	+3.5	+2.1	+0.6	+0.6	+4.2	+2.0	+4.1	+3.2	+1.1	+1.6	−4.1	−3.3	+1.3
North Pacific	+5.4	+3.0	+2.3	+3.6	+4.0	+0.9	+2.0	+0.6	+1.0	+1.0	−2.4	−0.4	+1.8
Middle Pacific	+2.0	+3.5	+3.7	+4.1	+5.4	+1.5	+4.2	+1.3	−0.3	−0.6	−2.9	−1.8	+1.7
South Pacific	+3.9	+4.1	+5.8	+6.0	+5.7	+2.3	+6.3	+4.6	+1.3	+2.6	−2.0	−1.1	+3.3
United States	+4.1	+5.4	−0.5	+1.0	+0.2	+2.5	+3.1	+1.1	+3.9	+3.4	+3.1	+3.9	[1] +2.6

[1] Annual departure.

TABLE 2.—*Precipitation departures, monthly and annual, 1931*

District	January	February	March	April	May	June	July	August	September	October	November	December	Sum
New England	−0.4	−1.0	+0.7	−0.2	+0.8	+2.1	+0.5	+0.1	−0.4	0.0	−2.1	−0.2	−0.1
Middle Atlantic	−1.4	−1.4	+0.1	−0.3	+0.9	−0.4	+0.6	+1.0	−1.2	−1.4	−1.9	−1.1	−6.5
South Atlantic	−1.2	−1.8	−0.2	−0.4	+0.6	−2.4	−0.3	−0.4	−3.0	−2.5	−1.9	+2.3	−11.2
Florida Peninsula	+2.4	+0.7	+3.8	+3.0	−0.9	−5.0	−1.2	−0.7	+5.3	−1.1	−1.3	+0.4	+5.4
East Gulf	−1.4	−1.9	−1.2	−1.7	−0.9	−2.8	+1.4	+0.7	−2.9	−0.9	−1.6	+3.9	−9.3
West Gulf	+0.6	+1.2	0.0	−0.7	−2.2	−1.2	+0.2	−0.3	−2.5	−0.6	+0.1	+2.2	−3.2
Ohio Valley and Tennessee	−2.6	−0.6	−1.4	−0.2	−0.5	−0.8	+0.5	+0.4	+0.4	−0.1	+0.1	+1.7	−3.1
Lower Lakes	−0.5	−1.0	−0.5	+0.3	+0.2	−0.7	−0.4	−0.6	+0.3	−0.7	−0.4	0.0	−4.0
Upper Lakes	−0.7	−0.8	+0.2	−1.1	−0.3	0.0	−0.6	−0.8	+1.4	+0.2	+1.1	−0.3	−1.7
North Dakota	−0.4	−0.1	+0.3	−1.2	−1.0	−1.4	+0.4	−0.2	+0.2	+0.3	−0.1	−0.1	−3.3
Upper Mississippi Valley	−1.0	−0.6	−0.1	−0.8	−1.1	−0.1	−1.1	+0.1	+0.9	+0.5	+3.0	+0.6	+0.3
Missouri Valley	−0.6	−0.2	0.0	−0.9	−0.5	−2.0	−1.2	+1.0	+0.2	−0.2	+3.2	+0.9	−0.3
Northern Slope	−0.6	−0.3	0.0	−0.6	−1.2	−0.9	−0.3	−0.6	0.0	−0.3	+0.2	−0.3	−4.9
Middle Slope	−0.4	+0.2	+0.6	+0.3	−0.8	−1.6	−1.4	−0.2	−0.6	−0.6	+2.5	−0.3	−2.3
Southern Slope	+1.0	+0.9	+0.1	+0.9	+0.1	−0.8	−0.8	−0.4	−2.4	+1.1	+0.8	+0.7	+1.2
Southern Plateau	−0.3	+0.7	−0.2	+0.8	−0.3	+0.2	−0.8	+0.8	+0.6	−0.2	+0.6	+0.1	+2.0
Middle Plateau	−0.6	−0.4	−0.5	+0.1	−0.5	−0.1	−0.1	−0.1	+0.1	−0.2	+0.6	+0.2	−1.5
Northern Plateau	−0.5	−0.7	+1.1	−0.6	−1.2	−0.2	−0.4	−0.4	0.0	−0.2	+0.1	+0.8	−2.2
North Pacific	0.0	−1.7	+1.5	−0.3	−1.3	+0.3	−0.6	−0.6	+0.9	0.0	−0.9	+0.8	−1.9
Middle Pacific	−0.2	−2.4	−2.0	−1.3	−0.1	+0.3	0.0	0.0	−0.5	−0.5	0.0	+3.7	−3.0
South Pacific	+1.1	+0.5	−1.9	+0.8	+0.3	+0.3	0.0	0.0	−0.1	−0.6	+0.9	+2.3	+3.0
United States	−0.4	−0.5	0.0	−0.2	−0.5	−0.8	−0.3	−0.1	−0.2	−0.4	+0.1	+0.9	−2.4

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

American national red cross.
Texas tornadoes and storms of May, 1930. 6 p. m. 28 cm. [Manifolded.]

Bentley, W. A., & Humphreys, W. J.
Snow crystals. 1st ed. New York. 1931. ix, 227 p. incl. front., illus. plates. 31½cm.

Bongards, H.
Lambrechts graphische Psychrometertafel für starkbewegte Luft. Luftgeschwindigkeit ≧2 m. p. s. n. p. n. d. chart (folded.) 22½ x 26½ cm.

Hannay, A. M., *comp.*
Influence of weather on crops: 1900–1930. A selected and annotated bibliography. [Washington. 1931.] 246 p. 23½ cm. (U. S. Agric. dept. Misc. pub. no. 118.)

Lindskog, Erik.
On the geographical distribution of fog in Sweden. n. p. n. d. 94 p. figs. 25 cm. (Georg. annaler. H. 1, 1931.)

Mellor, H. B., *& others.*
Studies of ultra-violet in daylight. 17 p. illus. 23 cm. (Paper presented before the silver anniv. conven. of the Illum. engin. soc., Pittsburgh, Pa., Oct. 13–16, 1931.)

Nichols, L. H.
Fourth report to the Quebec forest industries association, limited. The burning of settler's slash and meteorological conditions in the province of Quebec during 1931. Quebec. 1931. 22 p. plates. charts. 28 cm.

Peppler, W.
Ergebnisse der mehrjährigen Messungen der Ortshelligkeit am Bodensee. p. 157–189. figs. 23 cm. (Sonderab.: 57. Hefte der Schrift. des Ver. für Gesch. des Bodensees und seiner Umgebung.) (Arbeiten der Drachenstation am Bodensee.)

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Wagner, A.
Zur Aerologie des indischen Monsuns. Leipzig. 1931. p. 196–238. figs. 22 cm. (Sonderdr.: Gerlands Beitr. zur Geophys., Bd. 30 (1931).)

Wulf, Oliver R.
Determination of ozone by spectrobolometric measurements. Washington. 1931. 12 p. figs. plates. 24½ cm. (Smith. misc. coll., v. 85, no. 9.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING DECEMBER, 1931

By HERBERT H. KIMBAL, in charge, solar radiation investigations

For a description of instruments and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged above the normal values for December at Washington and Madison and close to normal at Lincoln.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at Chicago, New York, and Miami as compared with the December normals for the respective stations; close to normal at Pittsburgh, and a deficit at Washington, Madison, Lincoln, Twin Falls, Fresno, Gainesville, and La Jolla. The last line in the table gives annual departures in percentages of annual totals.

Skylight polarization measurements made on 4 days at Washington give 61 for the mean percentage of polarization, with a maximum of 65 per cent on the 2d and 6th. At Madison, polarization measurements made on three days early in the month give a mean of 72 per cent with a maximum of 77 per cent on the 1st. These are above the corresponding averages for each station in December.

TABLE 1.—*Solar radiation intensities during December, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
		Sun's zenith distance									
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Dec. 2	2.49	0.79	0.93	1.09	1.31	------	------	1.12	0.95	0.85	2.74
Dec. 7	3.15	------	1.00	1.18	1.36	------	------	1.12	0.86	0.75	2.26
Dec. 15	3.30	0.90	1.06	1.11	1.33	------	------	1.06	0.83	0.58	2.87
Dec. 16	3.81	------	0.97	1.13	1.38	------	------	------	------	------	2.74
Dec. 23	8.18	0.93	------	------	------	------	------	------	------	------	6.02
Means	------	0.87	0.99	1.13	1.34	------	------	1.10	0.88	0.73	------
Departures	------	+0.08	+0.09	+0.08	+0.11	------	------	+0.06	−0.03	−0.06	------

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Dec. 1	2.49	------	------	------	1.42	------	------	------	------	------	1.96
Dec. 2	2.87	------	------	1.23	------	------	------	------	------	------	3.00
Dec. 3	3.30	0.95	1.04	1.18	------	------	------	------	------	------	3.15
Dec. 7	1.37	------	------	1.34	------	------	------	1.26	------	------	1.24
Dec. 14	2.36	1.10	1.15	1.10	------	------	------	------	------	------	2.26
Means	------	(1.02)	(1.10)	1.21	(1.42)	------	------	(1.26)	------	------	------
Departures	------	+0.06	±0.00	±0.00	+0.07	------	------	+0.02	------	------	------

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Dec. 1	2.36	1.05	1.13	1.29	------	------	------	1.23	1.09	0.88	3.30
Dec. 2	3.00	------	------	1.20	------	------	------	1.23	1.12	1.02	4.17
Dec. 11	6.50	------	0.99	1.19	------	------	------	1.25	1.11	1.00	3.81
Dec. 14	2.26	0.90	1.09	1.26	------	------	------	1.23	1.11	------	3.00
Dec. 15	2.62	0.79	1.04	1.10	------	------	------	1.21	1.07	1.05	3.30
Dec. 16	3.15	0.84	0.99	1.15	------	------	------	1.15	1.04	------	3.63
Means	------	0.90	1.05	1.20	------	------	------	1.22	1.09	0.99	------
Departures	------	−0.04	−0.01	−0.02	------	------	------	+0.02	+0.02	+0.03	------

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week, beginning	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	Fairbanks
	Average daily totals											
1931	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 3	156	115	110	90	112	103	85	142	163	220	376	2.0
Dec. 10	133	113	156	112	85	163	78	187	170	250	367	1.5
Dec. 17	118	74	137	90	83	118	82	189	169	188	364	1.2
Dec. 24	137	66	87	64	160	101	65	204	122	202	274	1.7
	Departures from weekly normals											
Dec. 3	+8	−6	−55	+18	+22	−37	+5	−76	−14	−42	+73	----
Dec. 10	−5	+1	−1	+40	−5	+37	+10	−22	+2	−10	+69	----
Dec. 17	−22	−47	−33	+13	−12	−10	+15	−14	+8	−69	+86	----
Dec. 24	−5	−58	−88	−16	+58	−51	−19	−36	−25	−36	−4	----
	Departures from annual normals											
Gr. cal./cm.[2]	−1,750	+1,965	−445	+2,938	+2,893	−5,846	−1,420	----	+1,718	----	----	----
Percentage	−1.4	+1.2	−0.3	+3.2	+3.1	−3.9	-------	----	+1.1	----	----	----

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1931	h m	°	°	°			
Dec. 1 (Mount Wilson)	13 50	+47.0	311.5	+13.0	------	9	------
		+67.0	331.5	+10.0	------	137	146
Dec. 2 (Naval Observatory)	10 30		No spots		------	------	------
Dec. 3 (Naval Observatory)	10 33		No spots		------	------	------
Dec. 4 (Mount Wilson)	12 0	−63.0	162.9	+12.0	------	67	67
Dec. 5 (Naval Observatory)	10 35		No spots		------	------	------
Dec. 6 (Naval Observatory)	10 23	−76.0	124.4	+12.0	31	------	31
Dec. 7 (Naval Observatory)	10 36	−54.0	133.1	+11.5	------	170	170
Dec. 8 (Naval Observatory)	12 47	−40.0	132.8	+11.5	------	278	278
Dec. 9 (Yerkes Observatory)	15 9	−28.5	129.9	+10.4	5	------	------
		−27.7	130.7	+11.7	------	138	------
		−27.7	130.7	+10.6	17	------	------
		−27.6	130.8	+10.0	17	------	------
		−26.1	132.3	+10.0	3	------	------
		−25.2	133.2	+13.8	5	------	------
		−25.1	133.3	+13.0	3	------	------
		−25.1	133.3	+12.2	------	14	------
		−22.8	135.6	+12.5	107	------	------
		−21.6	136.8	+11.9	210	------	519
Dec. 10 (Naval Observatory)	10 17	−38.0	109.8	+4.0	------	62	------
		−14.0	133.8	+11.0	------	340	402
Dec. 11 (Naval Observatory)	11 20	−23.0	111.0	+4.0	------	154	------
		−1.0	133.0	+11.0	------	401	555
Dec. 12 (Yerkes Observatory)	14 18	−10.2	109.1	+4.3	7	------	------
		−9.7	109.6	+5.3	5	------	------
		−9.3	110.0	+4.1	2	------	------
		−6.3	113.0	+4.3	------	48	------
		−5.4	113.9	+4.7	22	------	------
		+10.5	129.8	+10.2	88	------	------
		+11.1	130.4	+11.0	2	------	------
		+11.9	131.2	+11.2	2	------	------
		+13.6	132.9	+11.7	------	169	------
		+16.6	135.9	+12.2	37	------	------
		+17.7	137.0	+12.4	37	------	419
Dec. 13 (Mount Wilson)	11 30	+4.0	111.6	+5.0	------	41	------
		+26.0	133.6	+12.0	------	298	339

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1931	h	m	°	°	°			
Dec. 14 (Naval Observatory)	12	43	+21.0	114.7	+4.0	15	------	------
			+39.0	132.7	+12.0	------	278	293
Dec. 15 (Naval Observatory)	11	20	+33.0	114.3	+4.0	25	------	------
			+50.0	131.3	+11.0	------	123	148
Dec. 16 (Naval Observatory)	10	30	+47.0	115.6	+4.0	15	------	------
			+63.0	131.6	+11.0	------	93	108
Dec. 17 (Naval Observatory)	10	39	+78.0	133.4	+11.0	------	93	93
Dec. 18 (Naval Observatory)	11	36	−69.0	332.7	+11.0	93	------	93
Dec. 19 (Naval Observatory)	10	37	−56.0	333.0	+11.5	93	------	93
Dec. 20 (Naval Observatory)	10	48	−41.5	334.3	+11.0	------	46	46
Dec. 22 (Yerkes Observatory)	14	23	−12.6	334.9	+12.1	15	------	15
Dec. 23 (Naval Observatory)	10	37	−4.0	332.3	+11.0	------	31	------
			+46.0	22.3	+14.0	31	------	62
Dec. 24 (Mount Wilson)	11	0	−80.0	242.9	−2.0	------	47	------
			−80.0	242.9	−12.0	84	------	------
			+5.0	327.9	+9.5	------	28	------
			+59.5	22.4	+11.0	------	27	186
Dec. 25 (Yerkes Observatory)	13	26	−64.9	243.6	−13.4	284	------	------
			−59.0	249.5	−2.5	19	------	303
Dec. 26 (Naval Observatory)	11	24	−54.0	242.4	−12.0	108	------	------
			−47.0	249.4	−1.5	15	------	123
Dec. 27 (Naval Observatory)	14	10	−40.0	241.7	−14.0	139	------	139
Dec. 29 (Naval Observatory)	15	2	−13.0	241.9	−13.0	------	139	139
Dec. 30 (Naval Observatory)	12	49	−1.0	241.9	−13.0	------	139	139
Mean daily area for December	------		------	------	------	------	------	175

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, FOR DECEMBER, 1931

(Data dependent alone on observations at Zurich and its station at Arosa)
[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

December, 1931	Relative numbers	December, 1931	Relative numbers	December, 1931	Relative numbers
1	20	11	a 35	21	8
2	16	12	37	22	16
3	7?	13	a 38	23	17
4	------	14	37	24	d 23
5	0	15	26	25	31
6	Ec 7	16	------	26	31
7	12	17	15	27	31
8	13	18	8	28	15
9	24	19	8	29	9
10	Ec —	20	8	30	a 11
				31	9

Mean: 28 days=18.3.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in charge]

By L. T. SAMUELS

Free-air temperatures were decidedly above normal and relative humidities were close to normal at all stations for December.

At the 1,000-meter level the resultant wind directions were close to normal at the northern stations but contained a considerably greater south component than normal at most of the southern stations. Resultant velocities were somewhat above normal at most stations.

At 3,000 meters the resultant directions were close to normal except at the extreme southern stations. At Key West a pronounced easterly component persisted to 4,000 meters as compared to the normal westerly direction at that level. Resultant velocities at 3,000 meters exceeded the normal appreciably in New England and at some southern stations.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during December, 1931*

TEMPERATURE (°C)

Altitude (meters) m. s. l.	Chicago, Ill.[1] (190 meters)	Cleveland, Ohio[1] (245 meters)	Dallas, Tex.[1] (149 meters)	Due West, S. C.[2] (217 meters)	Ellendale, N. Dak.[2] (444 meters)	Hampton Roads, Va.[3] (3 meters)	Omaha, Nebr.[1] (299 meters)	Pensacola, Fla.[3] (2 meters)	San Diego, Calif.[3] (9 meters)	Washington, D. C.[3] (2 meters)
Surface	1.7	2.3	7.2	9.1	−6.0	8.1	0.1	16.3	12.4	3.2
500	1.7	2.3	8.7	9.8	−5.4	7.2	0.7	15.8	10.8	4.6
1,000	1.3	1.5	8.6	9.9	−1.0	6.1	2.4	15.7	8.7	4.2
1,500	0.9	0.3	8.0	9.5	−0.1	------	3.0	------	------	------
2,000	0.0	−0.8	6.7	7.9	−1.9	4.1	1.7	12.1	4.9	1.8
2,500	−1.7	−2.5	4.8	6.0	−4.3	------	−0.6	------	------	------
3,000	−4.0	−4.8	2.6	3.4	−6.8	0.6	−3.1	7.0	0.9	−0.4
4,000	−9.4	−9.3	−3.9	------	−13.7	------	−9.5	------	−5.7	------
5,000	−16.5	−14.6	−11.0	------	−19.7	------	−16.7	------	−13.6	------
6,000	------	------	−16.2	------	------	------	−23.9	------	------	------

RELATIVE HUMIDITY (PER CENT)

Altitude (meters) m. s. l.	Chicago	Cleveland	Dallas	Due West	Ellendale	Hampton Roads	Omaha	Pensacola	San Diego	Washington
Surface	85	82	86	87	88	76	86	90	59	77
500	79	78	72	76	85	66	79	82	58	67
1,000	67	72	58	66	60	64	60	73	54	60
1,500	57	63	51	54	52	------	43	------	------	------
2,000	49	56	45	53	56	41	37	63	40	46
2,500	45	50	42	42	56	------	36	------	------	------
3,000	44	49	37	34	56	32	36	65	34	32
4,000	40	44	35	------	83	------	35	------	36	------
5,000	30	39	36	------	65	------	32	------	60	------
3,000	------	------	10	------	------	------	24	------	------	------

[1] Airplanes (Weather Bureau). [2] Kites. [3] Airplanes (Navy).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during December, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 29 E	1.1	N 78 W	1.6	S 27 W	1.3	N 74 W	4.2	S 76 W	0.9	S 69 W	1.9	S 87 W	0.5	N 48 E	1.2	N 60 W	1.0	S 66 W	2.2	N 48 E	0.7	S 78 E	3.4
500	----	---	S 9 W	1.7	S 64 W	4.5	----	---	S 86 W	4.2	S 77 W	5.7	S 54 W	3.2	N 65 W	1.4	N 65 W	1.4	----	---	S 12 E	3.8	S 69 E	8.9
1,000	----	---	S 22 W	3.0	N 83 W	7.4	----	---	S 84 W	6.7	N 84 W	7.9	S 70 W	4.2	S 83 W	2.9	N 51 W	3.6	S 62 W	6.9	S 5 W	3.8	S 59 E	8.0
1,500	----	---	S 19 W	4.4	N 62 W	10.6	----	---	N 83 W	12.8	N 87 W	10.7	S 49 W	5.5	S 84 W	5.8	N 60 W	5.0	S 79 W	9.5	S 41 W	4.4	S 57 E	6.0
2,000	N 23 W	1.8	S 72 W	5.2	N 62 W	14.1	N 82 W	7.4	N 87 W	10.3	N 85 W	11.3	S 60 W	6.9	W	8.8	N 64 W	8.3	N 89 W	9.3	S 57 W	5.2	S 54 E	5.1
2,500	N 71 W	3.9	S 44 W	7.0	N 61 W	16.3	N 86 W	9.3	----	---	N 87 W	12.9	S 64 W	8.9	N 83 W	8.1	N 70 W	8.5	N 87 W	9.4	S 44 W	5.5	S 52 E	3.9
3,000	N 71 W	5.8	S 51 W	9.2	N 55 W	21.3	N 82 W	7.1	----	---	----	---	S 67 W	10.5	S 89 W	8.9	N 76 W	9.9	N 87 W	10.7	----	---	S 57 E	4.3
4,000	N 79 W	8.7	----	---	----	---	S 89 W	9.0	----	---	----	---	S 80 W	10.2	----	---	N 70 W	14.5	----	---	----	---	S 40 E	3.4
5,000	S 77 W	7.2	----	---	----	---	S 88 W	6.8	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---
6,000	----	---	----	---	----	---	N 72 W	2.4	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---

Altitude (meters) m. s. l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (89 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 42 W	0.3	S 58 E	0.7	S 2 E	0.7	N 62 E	1.2	S 68 E	1.6	S 64 W	0.8	S 30 E	0.9	S 61 E	1.5	S 26 E	3.2	S 75 E	0.2	S 49 E	2.1	N 51 W	1.4
500	N 73 E	0.4	S 56 E	1.5	S 16 W	0.8	S 32 E	2.9	S 26 E	2.3	S 34 W	2.1	S 58 W	2.9	S 77 E	2.3	----	---	N 55 W	0.1	S 3 E	6.6	N 70 W	7.3
1,000	N 30 E	0.3	S 17 E	5.6	S 65 W	2.6	S 29 W	4.8	S 47 W	1.8	S 66 W	3.7	S 60 W	8.3	S 78 E	1.9	----	---	N 65 W	2.7	S 16 W	9.8	N 73 W	9.6
1,500	N 60 W	1.9	S 26 W	6.4	S 52 W	4.2	S 38 W	2.5	S 55 W	4.0	S 57 W	5.1	S 67 W	8.6	S 37 E	1.5	S 11 E	4.3	N 46 W	4.5	S 23 W	11.7	N 68 W	13.6
2,000	N 68 W	3.7	S 35 W	9.9	S 89 W	5.1	S 54 W	7.4	S 62 W	4.5	S 72 W	6.0	N 86 W	8.5	S 22 W	0.3	S 6 W	5.9	N 44 W	6.3	S 19 W	11.3	N 70 W	15.0
2,500	N 62 W	3.4	S 41 W	10.9	S 85 W	7.5	S 57 W	8.0	S 58 W	5.1	S 79 W	6.9	S 84 W	9.6	N 89 W	2.6	S 20 W	5.5	N 53 W	8.6	----	---	----	---
3,000	N 47 W	3.8	S 44 W	12.3	N 78 W	10.8	S 52 W	5.8	S 72 W	3.4	S 78 W	8.9	N 89 W	9.4	N 73 W	4.4	S 48 W	3.9	N 34 W	7.1	----	---	----	---
4,000	----	---	S 44 W	9.6	----	---	----	---	S 67 W	2.5	S 85 W	5.8	N 80 W	10.5	N 83 W	7.5	N 57 W	5.2	----	---	----	---	----	---
5,000	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---	----	---

TABLE 3.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during December, 1931*

	Dallas, Tex.[1]	Due West, S. C.[2]	Ellendale, N. Dak.[2]	Chicago, Ill.[1]	Cleveland, Ohio[1]	Omaha, Nebr.[1]
Mean altitudes, meters, m. s. l., reached during month	5,285	2,091	3,192	4,678	4,914	5,838
Maximum altitudes, meters, m. s. l., reached	5,982	3,570	5,161	5,273	5,671	6,547
Number of flights made	32	29	28	30	30	26
Number of days on which flights were made	31	29	28	30	30	25

[1] Airplanes. [2] Kite.

AEROLOGICAL OBSERVATIONS FOR THE YEAR 1931

[The Aerological Division, W. R. Gregg, in charge]

By L. T. SAMUELS

Table 1 shows the mean free-air temperatures and relative humidities for the year at Due West, Ellendale, and Washington, D. C., and for the parts of the year indicated at the other stations. Kite observations were discontinued during the year at Broken Arrow, Groesbeck, and Royal Center and regular daily airplane observations started at Chicago, Cleveland, Dallas, and Omaha.

An inspection of the departures from the normal free-air temperatures (not shown in table) for the corresponding periods at the various stations shows small negative values at all levels at Due West and moderately large positive departures at Ellendale and Washington, where full year records were obtained. Approximate normals for Dallas were obtained by interpolating latitudinally between Groesbeck and Broken Arrow. From these it is found that the free-air temperatures at Dallas and Omaha (the latter based on normals of the Drexel, Nebr., kite station) for the latter half of the year were above normal at all levels. The largest departures occurred at Omaha where they were nearly 4° C. at the 2,500 meter level. Positive departures of equal magnitude are found when the mean temperatures for Chicago are compared with the normals for Royal Center, situated 100 miles to the southeast.

TABLE 1.—*Mean free-air temperatures and humidities obtained by airplanes (or kites) during year 1931*

TEMPERATURE (°C)

Altitude (meters) m. s. l.	Broken Arrow, Okla.[1] (233 meters)	Chicago, Ill.[2] (190 meters)	Cleveland, Ohio[2] (245 meters)	Dallas, Tex.[2] (149 meters)	Due West, S. C. (217 meters)	Ellendale, N. Dak. (444 meters)	Groesbeck, Tex.[3] (141 meters)	Omaha, Nebr.[4] (299 meters)	Royal Center, Ind.[5] (225 meters)	Washington, D. C. (Naval Air Sta.) (2 meters)
Surface	9.3	12.6	12.4	18.2	15.3	7.3	10.4	10.4	8.3	11.8
500	8.6	13.4	13.3	19.3	14.5	7.3	9.8	11.1	6.7	11.7
1,000	7.0	12.8	12.8	18.6	12.6	7.5	7.9	12.3	4.7	10.2
1,500	4.9	10.6	10.4	16.6	10.0	6.1	6.5	11.3	2.7	------
2,000	2.8	8.0	8.1	14.1	7.5	3.9	4.5	9.3	0.7	5.8
2,500	0.2	5.5	5.8	11.5	4.9	1.2	2.1	6.8	−1.3	------
3,000	−2.4	2.8	3.4	8.8	2.2	−1.6	−0.4	3.9	−3.5	1.4
4,000	−8.6	−2.9	−1.5	2.5	−3.8	−7.5	−6.5	−2.6	−8.8	−3.8
5,000	−13.5	−8.9	−6.7	−2.0	−9.8	−13.9	------	−9.4	−14.7	−10.0
6,000	------	------	−12.3	−8.0	------	−19.6	------	−16.6	−21.6	------

RELATIVE HUMIDITY PER CENT

Altitude (meters) m. s. l.	Broken Arrow, Okla.[1]	Chicago, Ill.[2]	Cleveland, Ohio[2]	Dallas, Tex.[2]	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.[3]	Omaha, Nebr.[4]	Royal Center, Ind.[5]	Washington, D. C.
Surface	72	84	83	79	74	72	77	82	74	74
500	67	73	75	71	69	71	67	75	73	63
1,000	62	65	67	63	64	60	61	60	69	58
1,500	59	61	65	60	62	56	53	53	63	------
2,000	54	57	61	58	59	54	50	48	59	54
2,500	52	52	55	55	55	54	48	45	56	------
3,000	51	50	51	51	51	54	42	45	55	47
4,000	47	45	43	47	48	55	46	42	54	42
5,000	39	37	40	41	56	57	------	40	54	28
6,000	------	------	47	51	------	55	------	37	54	------

[1] January to May, inclusive, only.
[2] July to December, inclusive, only.
[3] January to April, inclusive, only.
[4] August to December, inclusive, only.
[5] January to June, inclusive, only.

The mean free-air temperatures for Royal Center for the first half of the year were slightly above the normals for the same period; those for Broken Arrow and Groesbeck for the first five and four months, respectively, were moderately below normal.

In Table 2 it will be noted that the highest average maximum altitude reached by airplane was 6,242 meters above sea level at Omaha and the highest single flight to 7,242 meters was also made at this station. An airplane flight was made on every day during the latter half of the year at Dallas; only one day was missed at Cleveland and this was due to mechanical trouble with the airplane; two days were missed at Chicago, and nine days at Omaha on account of unfavorable flying weather.

There were 14 new pilot balloon stations established and 2 closed during 1931, making a total of 69 such stations in operation at the end of the year. Of these, 3 are located in Alaska and 1 in Porto Rico.

TABLE 2.—*Observations by means of airplanes, kites, captive and limited-height sounding balloons during the year 1931*

	Broken Arrow, Okla.[1]	Chicago, Ill.[2]	Cleveland, Ohio[2]	Dallas, Tex.[2]	Due West, S. C.[1]	Ellendale, N. Dak.[1]	Groesbeck, Tex.[1]	Omaha, Nebr.[2]	Royal Center, Ind.[1]
Mean altitudes (meters), m. s. l., reached during month	2,861	4,861	5,586	5,526	2,679	3,254	2,334	6,242	3,219
Maximum altitude, (meters), m. s. l., reached	[3] 5,906	5,692	6,355	6,304	[3] 5,477	[3] 6,324	4,702	7,242	[3] 9,445
Number of flights made	165	182	183	184	362	355	99	139	182
Number of days on which flights were made	[4] 151	[5] 182	[5] 183	[5] 184	346	338	[6] 99	[7] 137	[8] 173

[1] Kites, captive or limited-height sounding balloons.
[2] Airplanes.
[3] Limited-height sounding balloon.
[4] January 1 to June 7, inclusive.
[5] July 1 to December 31, inclusive.
[6] January 1 to May 16, inclusive.
[7] August 8 to December 31, inclusive.
[8] January 1 to June 30, inclusive.

WEATHER IN THE UNITED STATES

[Climatological Division, OLIVER L. FASSIG, in charge]

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The continuation of abnormally warm weather during December in practically all sections east of the Rocky Mountains, and generous widespread precipitation in the interior and Southern States, were the outstanding features. The temperature for the month ranged generally from 4° to 12° above normal east of the Great Plains, except that in the extreme Northeast it was not so warm. The greatest plus departures for the month extended from Kentucky, Missouri, and eastern Kansas northward. West of the Rocky Mountains, temperatures were unusually low in many places, while in the Pacific coast sections they were only slightly below the normal. The precipitation was above the average in most areas, though along much of the Atlantic coast, in the Rocky Mountain region, and eastward therefrom along the Canadian border to the Great Lakes it was generally below the normal. Between the Appalachian and Rocky Mountains, except in eastern Oklahoma and portions of the adjacent States, the amounts were unusually generous, with many sections having from one and one-half to four times the normal. It was heavy in California also, where some stations reported nearly two and one-half times the average. In the western mountains snowfall was unusually heavy, while in the East but little snow fell.

TEMPERATURE

The first half of December continued the temperature features of the latter part of November, the eastern half of the country having mild weather, as a rule, and the western half severe cold. The temperature at this time was particularly low, compared with normal, in the Plateau and Rocky Mountain regions, and the first week saw comparatively cold weather in Texas and Louisiana as well; while some portions of the Missouri Valley, the Lake region, and the extreme Northeast likewise were moderately colder than normal about the 4th to 7th.

After the middle of the month the western half of the country was usually warmer than normal, especially the Plains and Rocky Mountain regions and those far western districts which are close to the Canadian boundary. Exceptions were to be found in the middle and southern Plateau region, and in the lower half of the Rio Grande Valley where abnormal cold continued till about the 20th. This half of December was extraordinarily warm for the time of the year in the north-central portion of the country, and was far warmer than normal elsewhere east of the Plains, except in the extreme northeastern portion where it was only moderately warmer.

As a whole, December was warmer than normal in very nearly the same part of the country that November had been; that is, east of the Rocky Mountains. However, the northern portions of Washington and Idaho, almost all of Montana, and the eastern portions of Wyoming and Colorado changed from colder than normal in November to slightly warmer in December, while the middle Rio Grande Valley made the reverse change.

Parts of New York and New England averaged but slightly warmer than normal in December, but otherwise all the country from the eastern Plains region and the lower Mississippi Valley eastward was far warmer than normal. In much of Wisconsin and States adjoining, also in portions of the extreme Southeast the mean temperature was 9° to 12° above normal.

In north-central and southeastern districts the month was usually the warmest December during the last 40 years, but was not so warm as December, 1889, save in a few localities.

The highest temperatures were close to 90° in a few of the southernmost States, and not far from 60° in northern border States and in the middle Plateau region. They occurred largely about the 11th to eastward of the Mississippi River, but at various dates between the 17th and the end of the month in practically every State west of that river.

The lowest readings were much below zero in the mountainous portions of the far West, also in the Dakotas, New York, and New England. As far north as Iowa, Ohio, and the mountains of Maryland zero temperatures were not experienced, while in Florida the lowest reading was 36°. The lowest temperatures occurred usually during the first half of the month, except in some of the Atlantic States, where they occurred during the final week.

PRECIPITATION

The first fortnight brought heavy rainfall to most portions of the Gulf and South Atlantic States, and the second week saw much precipitation also in the Ohio Valley, New England, and the greater part of the far Southwest.

The third week of the month was a notable period for precipitation in the extreme Northwest, while from Alabama and northern Georgia westward to eastern Texas heavy rainfall continued. The latter part of the month saw much precipitation in the far West, especially in California; while the middle Gulf region, the Carolinas, New England, and the Missouri and lower Ohio Valleys had considerable amounts.

As a whole, December was a month of liberal precipitation, and the distribution over the country was comparatively good. In the Gulf States, the lower Mississippi Valley, and the interior of the South Atlantic States there was considerably more than normal. The immediate South Atlantic coast had usually less than normal, though sufficient, as a rule, to considerably relieve the intense dryness developed by the fall months. In Tennessee, Mississippi, Louisiana, and eastern Arkansas the heavy December rainfall was detrimental, because of large falls in the months preceding.

From North Dakota to Michigan there was scanty precipitation in the northern portions of the respective States, but about normal or somewhat more than normal in the southern portions. The middle and lower Missouri Valley generally had far more precipitation than normal. At St. Joseph, Mo., this was the wettest December of the past 20 years. The Ohio Valley and the upper Mississippi Valley from northeastern Iowa southward had usually somewhat more precipitation than normal, and the same was true of considerable portions of the lower Lake region and of northern and eastern New England. Central Kansas, western Texas, and eastern New Mexico generally received greater than average amounts. The Pacific coast region and the western half of the Plateau region had far more than normal, particularly central and southern California.

Deficiencies were noted in central and northeastern Florida, in the middle Atlantic area and southwestern New England, from central Oklahoma to southwestern Missouri, in most of Montana and of western Nebraska, and nearly everywhere near the Rocky Mountain Divide.

SNOWFALL

The features of December snowfall greatly resembled those of November. In the eastern half of the country there was not very much near the Canadian boundary, and farther south none of consequence in the majority of districts where snow is anticipated. Near the Ohio River, along Lake Erie, and from eastern Pennsylvania to southern New England several stations reported no measurable snowfall, and most others found the December total the least of record.

In the middle and northern Plains there was moderate snowfall but usually less than normal except in South Dakota.

In the far West the snowfall at elevated stations was generally much greater than normal, several stations finding it the snowiest December for 10 years or longer. The supply remaining at the end of December in areas where storage toward the stream flow of next summer is important was very satisfactory in most of the States which lie west of the Continental Divide, and in considerable portions of New Mexico and Colorado also.

SUNSHINE AND RELATIVE HUMIDITY

More than the usual amount of sunshine for December prevailed generally in the Southeast, while in the far Southwest less than the average was received. Elsewhere about the normal amount prevailed. The relative humidity was generally above normal except in much of the Northeast, portions of the northern Rocky Mountain region, and the northern Pacific Coast States. However, almost everywhere the departures from the normal were small.

SEVERE LOCAL STORMS, DECEMBER, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Shelby County, Tenn.	6–13				$100,000	Rain and flood	Chief damage to roads	Official, U.S. Weather Bureau.
Block Island, R. I.	7	2:50–3:20 p. m.		3		Wind squall	Sloop and crew lost; steamboat disabled	Do.
South Carolina (western)	8–9					Glaze	Wires and trees broken; communication services impaired considerably.	Do.
Mississippi (delta counties).	8–24					Rain and floods	60,000 acres affected	Do.
Texarkana (near), Tex.	11	2 a. m.	200	2	10,000	Tornado	Several buildings damaged or destroyed; 9 persons injured.	Do.
Hortman (near), La.	13	1:35 a. m.	50–500	2	8,700	do	Buildings, crops, and timber damaged; path 3 miles long.	Do.
Columbia and Ouachita Counties, Ark.	13	A. m.		1		Tornado and downpour.	Scores of buildings wrecked, chiefly at Waldo, Stephens, and Camden; bridges and embankments washed out; 15 injured.	Post (Washington, D. C.).
Owings Mills and Rockville, Md.	14	P. m.		2		Wind	Trees and poles blown down; minor damage to other property.	Official, U.S. Weather Bureau.
Eureka, Calif., and vicinity.	17					do	Considerable damage to telephone, telegraph, power lines, and buildings.	Do.
Simpson County, Miss.	30	P. m.		5	50,000	Probably tornado.	50 persons injured; character of damage not reported.	Do.
Auburn (near), Ala.	30–31					Wind	Several buildings destroyed; trees uprooted	Do.
Roberson Springs (near), Ala.	30–31			4	4,000	Tornado	Several homes demolished; path 10 miles long	Do.
Montgomery, Ala.	31	2–4 a. m.				Wind	Large windows broken; many telephones put out of order.	Do.
Gadsden and adjacent counties, Fla.	31				10,000	Winds	Several large tobacco barns razed; buildings unroofed; slats, telephone, telegraph wires, and pine timber damaged; fruit blown off.	Do.
Boone County, Iowa	31					Glaze	750 telephone and telegraph poles blown down; trees broken; highways hazardous.	Do.

RIVERS AND FLOODS

By RICHMOND T. ZOCH

[River and Flood Division, Montrose W. Hayes in charge]

There were numerous overflows during December. However, except in the Tallahatchie and Yazoo Rivers of Mississippi, no flood caused any great damage. In some instances no loss of any kind occurred.

The following is a statement of flood losses:

Tangible property totally or partially destroyed, such as buildings, fences, factories, highways, bridges, railroads, etc.:	
Tombigbee River (Alabama)	$2, 500
Grand River (Missouri)	5, 000
Green River (Kentucky)	200
Barren River (Kentucky)	1, 000
Sulphur River (Texas and Louisiana)	1, 100
Total	9, 800
Matured crops:	
Tombigbee River	200
Sulphur River	5, 000
Total	5, 200
Livestock and other movable property:	
Tombigbee River	900
Sulphur River	175
Total	1, 075
Suspension of business including wages of employees:	
Tombigbee River	5, 500
Sulphur River	1, 200
Total	6, 700

A report of the losses caused by the floods in the Black, Ouachita, St. Francis, Tallahatchie, Yazoo, and Atchafalaya Rivers will be given in a later issue of the MONTHLY WEATHER REVIEW.

The final report on the flood in the Des Moines River during November gives the loss as $10,000, all of which was to unhoused crops.

The estimated money value of property saved by warnings was as follows:

Tombigbee River	$23, 000
Green River	500
Barren River	10, 000
West Fork of White River (Indiana)	1, 500
Ohio River	11, 000
Sulphur River	14, 000
Sabine River (Texas and Louisiana)	10, 000
Total	70, 000

The accompanying table gives the rivers which reached or exceeded the flood stage during December. In cases where the flood continued into January the crest given is the highest stage reached during December and may or may not be the actual crest for the entire flood.

Table of flood stages in December, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	Feet			Feet	
Chenango: Sherburne, N. Y.	8	15	15	8. 2	15
Saluda:					
Pelzer, S. C.	7	3	5	8. 2	4
		8	10	7. 2	10
		14	15	8. 2	15
		21	22	7. 6	22
Chappelis, S. C.	14	5	7	16. 8	6
Broad: Blairs, S. C.	15	4	5	17. 5	5
		14	15	15. 3	15

Table of flood stages in December, 1931—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE—con.	Feet			Feet	
Santee:					
Rimini, S. C.	12	8	10	13. 0	10
		16	22	13. 7	19
		25	26	12. 9	26
Ferguson, S. C.	12	11	14	12. 1	13
		18	28	12. 7	22
Broad: Carlton, Ga.	15	5	5	15. 8	5
Savannah: Ellenton, S. C.	14	7	29	18. 6	26
EAST GULF OF MEXICO DRAINAGE					
Oostanaula: Resaca, Ga.	22	15	17	23. 3	16
Tombighee:					
Aherdeen, Miss.	34	15	20	39. 6	16
Columhus, Miss.	25	19	21	26. 7	20
Lock 4, Demopolis, Ala.	39	20	[1]	47. 7	26
Pearl: Jackson, Miss.	20	18	[1]	23. 6	27
West Pearl: Pearl River, La.	13	21	[1]	14. 2	26
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
Illinois:					
Havana, Ill.	14	Nov. 29	4	14. 1	1-2
Peru, Ill.	14	Nov. 22	7	17. 5	Nov. 24
		13	20	14. 7	15
Missouri Basin					
Grand:					
Gallatin, Mo.	20	12	12	21. 5	12
Chillicothe, Mo.	18	12	13	21. 2	12
Brunswick, Mo.	12	Nov. 18	1	18. 9	Nov. 27
Missouri: St. Charles, Mo.	25	Nov. 29	1	26. 1	Nov. 30
Ohio Basin					
Walhonding: Walhonding, Ohio	8	14	14	10. 2	14
Scioto:					
Circleville, Ohio	10	13	15	13. 3	15
Chillicothe, Ohio	16	16	16	16. 0	16
Barren: Bowling Green, Ky.	20	14	15	21. 9	15
Green:					
Lock 6, Brownsville, Ky.	28	15	15	30. 3	15
Lock 4, Woodbury, Ky.	33	14	18	38. 5	16
Lock 2, Rumsey, Ky.	34	18	20	34. 8	19
West Fork of White:					
Elliston, Ind.	19	13	16	22. 0	14
Edwardsport, Ind.	15	13	19	18. 1	17
East Fork of White: Seymour, Ind.	10	14	15	11. 5	14
Elk: Fayetteville, Tenn.	14	24	24	14. 3	24
Ohio:					
Shawneetown, Ill.	33	19	22	33. 6	21
Dam 50, Fords Ferry, Ky.	32	19	24	33. 9	21
White Basin					
Black: Black Rock, Ark.	14	31	[1]	14. 3	31
Red Basin					
Sulphur:					
Ringo Crossing, Tex.	20	17	19	24. 2	18
Finley, Tex.	24	22	26	25. 5	23
Lower Mississippi Basin					
St. Francis:					
Chaonia, Mo.	22	31	[1]	23. 5	31
Fisk, Mo.	20	31	[1]	20. 0	31
Tallahatchie: Swan Lake, Miss.	24	15	[1]	33. 9	31
Yazoo:					
Greenwood, Miss.	35	23	[1]	36. 0	26
Yazoo City, Miss.	23	31	[1]	23. 2	31
Ouachita:					
Arkadelphia, Ark.	12	14	14	17. 3	14
		18	19	14. 1	18
Camden, Ark.	30	18	26	34. 9	22
Monroe, La.	40	25	[1]	41. 3	31
Atchafalaya Basin					
Atchafalaya: Atchafalaya, La.	22	27	[1]	22. 4	30-31
WEST GULF OF MEXICO DRAINAGE					
Sabine: Logansport, La.	25	18	27	27. 8	22
PACIFIC SLOPE DRAINAGE					
San Joaquin Basin					
Kings: Piedra, Calif.	12	28	28	14. 7	28
Columbia Basin					
Coast Fork: Saginaw, Oreg.	9	31	31	10. 0	31
Long Tom: Monroe, Oreg.	10	21	[1]	13. 0	28
Willamette: Harrisburg, Oreg.	10	31	31	10. 0	31

[1] Continued into January, 1932.

All dates in December unless otherwise indicated.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[By the Marine Division, W. F. McDONALD in Charge]

NORTH ATLANTIC OCEAN

By W. F. McDONALD

The pressure situation.—The average barometric pressure for December, 1931, indicated in general a weakening of the usual Icelandic LOW, which occurred during the middle and latter part of the month. For the month as a whole the barometer averaged one-third of an inch above normal on the Irish coast, with excess pressures in lesser amounts at all stations representing the northeastern Atlantic area. (See Table 1.) Pressure departures were slightly below normal over the northwestern Atlantic, central over the Canadian Maritime Provinces, where storms were most numerous and quite persistent. Normal pressures prevailed in mid-Atlantic and over the West Indies.

The Atlantic HIGH was well developed at the opening of the month, dominating the whole ocean between the American and European coasts south of latitude 45°. About the end of the first week, however, the continuity of this HIGH was broken by the southward extension of a deep LOW over Newfoundland, and high pressure attained full transoceanic development thereafter in only one or two brief spells. High pressure was remarkably persistent over western Europe and also during much of the month, between the Azores and the European coast. A severe cold wave was reported from western Europe about the 20th.

Cyclones and gales.—Storminess was more pronounced over the western than over the eastern portion of the Atlantic, but the month did not rank as an unusually stormy December. The total number of gales reported from ship routes was rather less than usual for the month, although whole gales or stronger were encountered at some place on the northern routes on about two-thirds of the days in the month, but in most cases the gales occurred west of longitude 30°. Within the last 10 days, gale conditions were reported far southward over the western Atlantic as a result of the development of several slow-moving LOWS which combined to form a persistent cyclonic storm central near Newfoundland but extending its influence at times well southward past Bermuda.

The highest winds of the month in no case exceeded force 11, although gales of that severity were reported by four ships, all westbound from north European ports, the German steamship *Dresden* and the American steamship *West Harcuvar* on the 5th, the American steamship *Ensley City* on the 15th, and the American steamship *Seattle Spirit*, on the 16th, as shown in the table of selected storm reports which accompanies this summary.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, December, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Reykjavik, Iceland [1]	29.55	+0.08	30.26	29	28.73	8
Lerwick, Shetland Islands [1]	29.88	+0.16	30.61	21	28.66	4
Valencia, Ireland [1]	30.27	+0.33	30.62	12	29.46	3
Lisbon, Portugal [1]	30.27	+0.16	30.50	4	29.89	30
Madeira [1]	30.12	+0.03	30.37	21	29.81	29
Horta, Azores [1]	30.15	+0.01	30.48	8	29.67	15
Belle Isle, Newfoundland [1]	29.69	−0.01	30.16	6	29.04	28
Halifax, Nova Scotia [1]	29.86	−0.09	30.44	[3] 9	29.38	15
Nantucket [2]	30.03	−0.02	30.61	8	29.50	22
Hatteras [2]	30.16	+0.03	30.57	8	29.85	4
Bermuda [1]	30.15	+0.03	30.40	4	29.78	29
Turks Island [1]	30.12	+0.09	30.20	[3] 13	30.02	29
Key West [2]	30.07	−0.01	30.18	19	29.80	31
New Orleans [2]	30.07	−0.06	30.40	15	29.61	30
Cape Gracias, Nicaragua [1]	29.90	−0.08	29.96	[3] 25	29.84	[3] 11

[1] All data based on a. m. observations only, with departures compiled from best available normals related to time of observations.
[2] Corrected 24-hour means, based on more than one observation daily.
[3] And other date or dates.

Charts VIII to XI cover selected days in December, to illustrate the stormier portions of the month on the North Atlantic.

Unusually heavy seas accompanying the storm of December 16th (shown on Chart IX) were reported in news dispatches to have made navigation exceedingly difficult for the eastbound Anchor liner *Tuscania*, which was forced on several occasions to come about to face the sea, and was once overwhelmed by a huge following wave that caused the death of one passenger and injured a number of others on deck at the time.

Fog.—Fog was mostly confined to the region of the Grand Banks and the New England coast, being reported in one or more localities on about half the dates in the month, but in no single 5-degree square on more than four days. Six dates with fog were reported from coastal waters of the northwestern Gulf of Mexico.

OCEAN GALES AND STORMS, DECEMBER, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Grete, Ger. S. S.	Hamburg	New York	50 12 N	27 30 W	Dec. 1	3 p, 1	Dec. 2	28.98	SSE	SSW, 8	WNW	—, 10	SSE-SW.
Examelia, Am. S. S.	Lisbon	do	43 00 N	35 58 W	Nov. 30	1 a, 1	do	29.70	S	W, 9	S	S, 10	S-SW-W.
West Harcuvar, Am. S. S.	Hamburg	Boston	50 20 N	26 09 W	Dec. 1	Noon, 2	do	29.36	SW	WSW, 7	W	WSW, 10	WSW-W.
Titus, Du. S. S.	Port Barrios	Amsterdam	41 37 N	48 40 W	Dec. 2	4.30 p, 2	do	29.28	SSE	N, 10	NNE	—, 10	SSE-S-W-N.
Winnebago, Br. S. S.	New York	Avonmouth	48 32 N	30 40 W	Dec. 3	Mdt, 3	Dec. 5	29.23	SSE	WSW, 9	SW	WNW, 10	SSE-WSW.
Polybius, Am. S. S.	Manchester	Beaumont, Tex.	53 27 N	4 38 W	Dec. 2	Noon, 3	Dec. 7	29.28	S	SW, 10	NW	W, 10	S-W.
Otho, Am. S. S.	St. Vincent	New York	37 30 N	65 30 W	Dec. 4	6 p, 4	Dec. 5	29.68	SW	SW, 6	NW	SW, 10	SW-W-NW.
Dresden, Ger. S. S.	Cobh	do	44 00 N	55 18 W	Dec. 5	3 p, 5	Dec. 8	29.02	SSW	SSW, —	NNW	NNW, 11	SSW-WNW.
West Harcuvar, Am. S. S.	Hamburg	Boston	48 56 N	40 12 W	do	11 p, 5	Dec. 7	29.20	WSW	S, 6	S	WSW, 11	S-WSW.
Missouri, Br. S. S.	London	New York	47 44 N	33 58 W	Dec. 6	5 p, 6	do	29.59	S	SW, 9	WSW	SW, 9	SW-WSW.
Cerinthus, Br. S. S.	Port Arthur	Antwerp	47 26 N	10 03 W	do	Noon, 6	do	29.68	NW	WNW, 5	N	NNW, 9	
Aden Maru, Jap. S. S.	Fowey	Portland, Me.	43 26 N	60 37 W	Dec. 7	3 p, 7	do	29.29	W	W, 8	W	W, 10	W-WNW-W.
Tiger, Nor. S. S.	Harstad, Norway.	Baton Rouge	61 58 N	20 15 W	do	10 a, 7	do	28.96	SSE	SE, 10	SW	—, 10	SE-SW.
Examelia, Am. S. S.	Lisbon	New York	41 50 N	58 32 W	do	6 a, 8	Dec. 9	29.43	S	WNW, 7	N	—, 10	WNW-W-NW.

Ocean gales and storms, December, 1931—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN—Con.			° ′	° ′				Inches					
Persephone, Danzig M. S.	Florida Straits.	Rotterdam	34 58 N	52 50 W	Dec. 7	3 p, 8	Dec. 10	29.77	S	WNW, 8	N	NNW, 10	WNW-NW.
Berlin, Ger. S. S.	Bremerhaven	New York	47 43 N	37 30 W	Dec. 8	1 p, 9	Dec. 9	29.20	SW	SSW, 9	SW	S, 9	SSW-NW.
Coahoma County, Am. S. S.	Antwerp	do	49 02 N	28 53 W	Dec. 6	3 p, 10	Dec. 10	29.68	NW	S, 10	NNE	S, 10	S-SSW-N.
Shickshinny, Am. S. S.	Manchester	Charleston	44 35 N	24 30 W	Dec. 11	8 a, 11	Dec. 12	29.91	SE	SE, 7	SE	—, 10	Steady.
Venezuela, Du. S. S.	Europe	Barbados	36 26 N	27 47 W	Dec. 10	5 a, 11	Dec. 11	29.76	SE	SE, 9	WSW	SE, 9	SE-SW.
Cripple Creek, Am. S. S.	Manchester	New Orleans	44 52 N	36 02 W	Dec. 11	10 a, 14	Dec. 16	28.89	SSE	SSW, 7	SW	W, 10	W-WNW.
Ensley City, Am. S. S.	Liverpool	Baltimore	45 50 N	47 05 W	Dec. 15	8 p, 15	Dec. 19	29.02	S	WSW, 8	W	W, 11	S-SW-NW.
Cold Harbor, Am. S. S.	Cork	Boston	47 45 N	49 30 W	Dec. 13	1 a, 16	Dec. 16	28.80	S	WSW, 10	NW	WSW, 10	SW-WSW.
Seattle Spirit, Am. S. S.	Nordenham	do	50 09 N	32 16 W	Dec. 16	—, 16	Dec. 18	29.38	S	S, 8	W	—, 11	
Exton, Am. S. S.	New York	Malta	39 56 N	61 15 W	Dec. 17	10 a, 18	do	29.87	W	WNW, 9	NW	WNW, 9	W-NW.
Maine, Dan. S. S.	Antwerp	Providence	41 30 N	58 49 W	Dec. 18	4 a, 18	do	29.61	WNW		NNW	—, 10	Steady.
Volendam, Du. S. S.	Rotterdam	New York	48 33 N	44 32 W	Dec. 15	3 a, 18	do	28.97	SE	NW, 10	W	NW, 10	SW-NW.
Kenbane, Br. S. S.	Fowey	Boston	49 07 N	37 20 W	Dec. 16	2 p, 19	Dec. 19	29.20	SSW	SW, 8	WSW	S, 10	SSE-WSW.
Exilona, Am. S. S.	Casa Blanca	do	41 09 N	57 24 W	Dec. 18	1 a, 20	Dec. 20	29.54	SW	NW, 7	NW	W, 10	NW-N-NE.
Independence Hall, Am. S. S.	Bordeaux	New York	35 00 N	58 00 W	Dec. 21	6 a, 21	Dec. 21	29.65	S	S, 9	N	—, 10	S-W-N.
Tiberius, Du. S. S.	English Channel.	San Juan	32 50 N	43 58 W	Dec. 22	3 p, 22	Dec. 22	29.40	SW	SW, 9	N	NNW, 9	
Poseidon, Du. S. S.	Port Barrios	Amsterdam	34 15 N	74 10 W	Dec. 25	5 a, 25	Dec. 28	29.85	NW	NW, 8	NW	—, 9	SW-NW.
Exeter, Am. S. S.	Marseille	New York	36 36 N	52 52 W	Dec. 26	11 a, 27	do	29.31	SW	SW, 10	NW	SW, 10	SW-WNW.
Trimountain, Am. S. S.	Manchester	Jacksonville	38 23 N	40 00 W	Dec. 28	2 p, 28	Dec. 29	29.69	ESE	S, 8	NW	SW, 9	SW-W-NNW.
Poseidon, Du. S. S.	Port Barrios	Amsterdam	37 50 N	52 30 W	Dec. 29	Mdt, 29	Dec. 30	29.46	SW	SW, 9	SE	SSW, 10	
City of Alton, Am. S. S.	Rotterdam	New York	43 46 N	50 02 W	Dec. 30	Noon, 30	do	29.01	SW	SW, 7	NW	NW, 10	SW-NW.
NORTH PACIFIC OCEAN													
Oregon, Am. S. S.	Otaru	San Francisco.	46 30 N	143 15 W	Dec. 1	1 a, 1	Dec. 2	29.60	NW	NW, 11	WNW	NW, 11	
Grays Harbor, Am. S. S.	Taku Bar	Seattle	46 52 N	165 53 E	do	Noon, 2	do	29.04	SSW	S, 12	W	S, 12	S-W.
Shelton, Am. S. S.	Hong Kong	San Francisco.	41 55 N	159 00 E	do	4 a, 2	do	29.31	S	WNW, 6	SW	S, 10	
Tacoma, Am. S. S.	Tacoma	Yokohama	49 50 N	174 15 E	Dec. 2		do	29.22	S	S, 11	SSW	S, 11	SSE-SSW.
Forthbank, Br. S. S.	Balboa	Kobe	26 46 N	157 50 W	Dec. 3	6 p, 3	Dec. 5	29.85	N	N, 9	NNE	N, 9	Steady.
Grays Harbor, Am. S. S.	Taku Bar	Seattle	49 19 N	177 35 W	Dec. 4	1 p, 4	Dec. 4	29.49	S	S, 10	NW	S, 10	S-W.
Shelton, Am. S. S.	Hong Kong	San Francisco.	45 35 N	173 02 E	do	3 a, 5	Dec. 5	29.44	SSE	S, 9	S	S, 10	SSE-S-NW.
Golden Sun, Am. S. S.	Dairen	do	37 28 N	151 30 W	do	2 p, 5	do	29.69	N	N, 10	ENE	N, 10	N-NE.
Emp. of Japan, Br. S. S.	Vancouver	Honolulu	45 50 N	130 05 W	Dec. 6	Noon, 6	Dec. 6	29.06	SE	N, 7	NW	NW, 12	SSW-W-NW.
Emma Alexander, Am. S. S.	San Diego	Seattle	47 04 N	124 54 W	do	8 p, 6	Dec. 7	29.16	ESE	S, 8	SSW	SW, 9	SSE-S-SW.
San Pedro Maru, Jap. M. S.	Kobe	San Francisco.	41 12 N	156 10 E	Dec. 7	4 p, 8	Dec. 9	29.38	SSW	NW, 8	WNW	NW, 10	W-NW-WNW.
Soyo Maru, Jap. M. S.	San Francisco.	Yokohama	44 05 N	163 43 E	Dec. 9	4 a, 9	Dec. 13	29.02	W	W, 8	SSE	WNW, 10	W-WNW.
Forthbank, Br. S. S.	Balboa	Kobe	29 37 N	172 45 E	Dec. 10	4 p, 10	Dec. 11	29.96	NE	NE, 9	NE	NE, 9	NE-N.
Pres. Hayes, Am. S. S.	Honolulu	do	26 23 N	171 52 E	do	6 p, 10	do	29.32	NW	N, 9	NNW	N, 10	Steady.
Nevada, Am. S. S.	Columbia River.	Yokohama	52 30 N	173 55 W	Dec. 11	2 p, 11	Dec. 13	29.53	SE	WSW, 4	W	W, 10	SSE-WSW.
Pres. Lincoln, Am. S. S.	Honolulu	San Francisco.	26 05 N	149 58 W	do	Mdt, 11	do	29.67	SE	SE, 7	E	E, 9	
Makawao, Am. S. S.	San Francisco.	Honolulu	32 19 N	137 00 W	Dec. 14	9 p, 14	Dec. 15	29.58	SE	SE, 9	SE	SE, 9	
Texas, Am. S. S.	Lamit Bay, P. I.	San Francisco.	39 33 N	155 25 W	do	Noon, 15	do	29.91	NNW	N, 7	N	N, 9	Steady.
Emma Alexander, Am. S. S.	Seattle	San Diego	48 00 N	124 52 W	Dec. 16	—, 17	Dec. 17	29.64	SE	S, 6	S	S, 10	SE-S.
Matsonia, Am. S. S.	San Francisco.	Honolulu	35 37 N	129 44 W	Dec. 17	3 p, 17	do	29.56	SSE	SSW, 9	WSW	SSW, 9	SSE-S-SSW.
Heian Maru, Jap. M. S.	Yokohama	Vancouver	50 34 N	151 43 W	Dec. 16	8 a, 18	Dec. 18	29.59	NW	NNW, 7		—, 10	N-NW.
Fernwood, Nor. M. S.	San Pedro	Yokohama	37 27 N	161 45 E	do	3 p, 18	do	29.87	S	NW, 11	NW	NW, 11	SE-NW.
Admiral Peoples, Am. S. S.	Portland	Wilmington	Off Cape Blanco Light.		do	6 a, 17	do	29.66	SSE	S, 6	SW	S, 11	S-SSE.
Northwestern, Am. S. S.	Seattle	Seward	60 14 N	146 40 W	Dec. 17	9 p, 17	do	29.28	NE	NE, 7	NW	NE, 9	NE-NW.
Melmay, Br. S. S.	Karatsu	New Westminster.	51 02 N	163 56 W	Dec. 19	4 p, 19	Dec. 21	[1] 29.59	S	S, 8	NW	WNW, 9	
Emma Alexander, Am. S. S.	Seattle	San Diego	43 15 N	124 42 W	Dec. 21	Noon, 21	do	29.44	SSE	SSE, 9	SW	SSE, 9	SSE-SW.
Yoseric, Br. S. S.	Koseir	Osaka	16 40 N	116 42 E	Dec. 20	4 p, 20	Dec. 25	29.99	NNE	NE, 8	NE	NE, 9	NNE-NE.
Mala, Am. S. S.	Puget Sound	Hawaiian Is.	43 28 N	133 00 W	Dec. 22	—, 23	Dec. 23	29.02	SW	SW, 10	WNW	SW, 10	SW-W.
Canadian Ranger, Can. S. S.	Balboa	Vancouver	45 10 N	125 04 W	do	2 p, 23	Dec. 24	29.17	S	S, 10	SSW	S, 10	S-SSW.
Emma Alexander, Am. S. S.	Seattle	San Diego	Off San Francisco		Dec. 23	4 p, 23	do	29.89	SSW	SSW, 6	SE	SE, 10	SSW-SE.
City of Elwood, Am. M. S.	Shanghai	San Pedro	37 18 N	146 15 W	Dec. 24	6 p, 25	Dec. 26	29.73	WSW	W, 9	NW	W, 9	WSW-W-NW.
Bellingham, Am. S. S.	Tacoma	Yokohama	35 59 N	141 58 E	Dec. 25	Noon, 25.	do	29.50	NNE	NNE, 10	NNE	NNE, 10	Steady.
Mala, Am. S. S.	Puget Sound	Hawaiian Is.	40 22 N	137 02 W	do	—, 25	do	29.22	SW	SW, 9	W	W, 11	W-NW.
Mojave, Am. S. S.	Seattle	San Pedro	43 40 N	124 55 W	do	3 a, 26	do	29.31	S	SSE, 10	SSE	SSE, 11	SSE-SW.
Takaoka Maru, Jap. S. S.	Yokohama	San Francisco.	35 25 N	145 50 E	do	9 p, 25	Dec. 27	[1] 29.65	N	N, 8	N	N, 10	Steady.
Melmay, Br. S. S.	Karatsu	New Westminster.	50 00 N	131 00 W	do	4 p, 26	do	[1] 28.95	SE	SSE, 10	SW	ESE, 11	
Adm. Farragut, Am. S. S.	Portland	San Francisco.	37 00 N	122 20 W	Dec. 26	3 a, 27	do	29.94	S	S, 9	SE	SE, 10	S-SE-S.
Olympia, Am. S. S.	Manila	do	36 30 N	154 02 E	Dec. 27	1 a, 27	do	[1] 29.45	N	N, 8	NW	N, 9	N-NNW.
Takaoka Maru, Jap. S. S.	Yokohama	do	39 35 N	155 24 E	Dec. 28	Noon, 29	Dec. 31	29.35	S	W, 11	N	W, 11	
Everett, Am. S. S.	Dairen	Seattle	49 46 N	176 45 E	do	2 p, 30	do	28.20	NNW	SW, 9	W	W, 11	S-SW-W.
Brandywine, Am. S. S.	Seattle	San Pedro	42 12 N	125 02 W	Dec. 29	2 p, 29	Dec. 30	[1] 29.84	SSE	SSE, —	SE	SE, 9	SSE-SE.
Hakonesan Maru, Jap. M. S.	Yokohama	San Francisco.	42 30 N	172 51 E	do	2 a, 30	do	29.08	SE	S, 11	W	S, 11	SSE-S-SSW.
Hikawa Maru, Jap. M. S.	do	Vancouver	49 00 N	179 30 W	do	6 p, 30	Dec. 31	28.67	SSE	SW, 9	W	WSW, 10	
Emp. of Russia, Can. S. S.	do	do	46 20 N	167 00 E	do	5 a, 30	do	28.41	S	WSW, 6	WNW	W, 11	WSW-WNW.

[1] Barometer uncorrected.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—The average pressure distribution for December, 1931, showed an elongated region of low barometer stretching in upper latitudes from the American coast far into the Bering Sea, with centers near St. Paul Island and in the Gulf of Alaska. At Dutch Harbor, near the usual center of action of the Aleutian LOW, the average pressure of 29.72 inches was almost two-tenths of an inch higher than that at St. Paul, which is a very unusual condition. In the Gulf of Alaska the LOW was maintained rather vigorously from the 13th until the close of the month and, because, for much of that period, it extended far southward, average pressures along the American coast were well below the normal almost to extreme southern California.

In consequence of the extensive cyclonic developments over the eastern part of the Pacific, the main body of the great North Pacific anticyclone was crested near midocean at about the thirtieth parallel, with a minor anticyclone prevailing for the greater part of the month west of southern and Lower California. In the Far East fewer cyclones than normal for December entered the sea from the continent, and an extensive bank of high pressure for the most part overlay eastern Asia and, in lesser degree, the Japanese Archipelago. The principal cyclones of the western waters of the Pacific seem to have originated over the Kuro Siwo Current.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure, at sea level, North Pacific Ocean and adjacent waters, December, 1931, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	29.87	−0.16	30.56	31st	29.26	22d.[3]
Dutch Harbor [1]	29.72	+0.16	30.34	6th	29.00	1st.
St. Paul [1] [2]	29.53	−0.05	30.40	14th	28.36	7th.
Kodiak [1]	29.51	−0.05	30.20	10th	28.88	17th.
Midway Island [1]	30.18	+0.17	30.42	20th	29.76	12th.
Honolulu [4]	30.01	0.00	30.24	20th	29.70	12th.
Juneau [4]	29.60	−0.19	30.14	10th	28.67	16th.
Tatoosh Island [4] [5]	29.78	−0.18	30.42	5th	29.06	23d.
San Francisco [4] [5]	30.04	−0.08	30.37	16th	29.63	28th.
San Diego [4] [5]	30.07	0.00	30.32	26th	29.72	9th.

[1] P. m. observations in averages; a. m. and p. m. in extremes.
[2] For 30 days.
[3] And on the 23d.,
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—Following hard upon the stormy weather of November, 1931, that of December was equally disturbed in northern and western waters, but far stormier off our American west coast. Here, on the 6th and 7th and from the 17th until the 29th, the coastal region was swept by intermittent gales that extended as far southward on the 23d and 27th as the latitude of San Francisco. The cyclone causing the gales of the 6th and 7th developed rather suddenly west of Vancouver Island and within a few hours had acquired its greatest intensity, with central pressure below 29.40 inches. The gales blew over the region between the coast and the one hundred and thirty-fifth meridian and for a time attained hurricane force near 46° N., 130° W.

The succeeding coastal gales occurred on the southeastern boundary region of the elongated cyclone, the central area of which lay over the Gulf of Alaska from the 13th to 31st. Coastwise steamers during this period encountered the most intense gales—of force 11 from southerly directions—on the 17th and 26th, south of North Head, Wash., and from westerly directions of similar force on the 26th west of Vancouver and near 40° N., 137° W. On the 23d and 27th whole gales (force 10) were reported off the central California coast, and fresh to strong gales over a long stretch of coast on other dates. Several vessels on the 26th were forced to heave to for hours in the violent storm.

Midway along the upper routes between the American coast and the Aleutian Islands gales were less frequent than elsewhere in the same latitudes. The greater part of the high winds occurred after the middle of the month here, but the highest reported velocity was on the 1st, when a northwest gale of force 11 was experienced near 46° N., 143° W. South of Dutch Harbor maximum forces of 11 to 12 occurred on the 22d and 28th. Between 170° W. and Japan, over a wide strip of ocean south of the fiftieth parallel stormy weather was frequent and severe. South and southwest of the western Aleutians winds of the higher forces, 11 to 12, were reported on the 2d, 18th, 29th, and 30th, in addition to those of lesser forces, 8 to 10, on many other days. The storm to hurricane forces of the 2d, 29th, and 30th were felt over a wide range of the sea.

Special mention should be made of a rather interesting disturbance which developed east of the Hawaiian Islands on the 6th. For upward of a week it remained practically stationary, its northward advance blocked by a middle-latitude anticyclone. By the 10th and 11th fresh to strong easterly gales were blowing on its north sector, in 27° to 29° N., 145° to 150° W. On the 14th, however, the HIGH gave way and the disturbance, accompanied by gales of force 8 to 9, quickly escaped to higher latitudes, where it joined with the cyclone then stretching southward from Alaskan waters.

Only one tropical disturbance of any intensity, and that of slight extent, occurred in December, 1931. This was a typhoon of the central Philippines and is described in the subjoined article by the Rev. Miguel Selga, S. J., director of the Philippine Weather Bureau.

Other moderately stormy weather in various parts of the Tropics was occasioned by strong northeast monsoons which rose to gale force on several days in the China Sea. On the 4th of the month trade winds of force 8 occurred west of the Hawaiian Islands, and on the 15th, 26th, and 27th northers of moderate gale force were experienced in the Gulf of Tehuantepec.

Winds at Honolulu.—The prevailing wind direction at Honolulu was from the east. The maximum velocity was 43 miles from the east on the 20th, during the prevalence of a very strong anticyclone to the northward.

Fog.—The occurrence of fog in December increased slightly over that of November along the northern routes, and decreased slightly in American coastal waters. Fog was reported on seven days along the length of coast between Eureka and San Diego, and on not to exceed three days in the foggiest of 5° squares in higher latitudes of the open Pacific. As a rule its occurrence was widely scattered, but on the 5th to 7th it was more evenly distributed.

THE TYPHOON OF VISAYAS, DECEMBER 5-6, 1931

By Rev. MIGUEL SELGA, S. J.

[Weather Bureau, Manila, P. I.]

The afternoon weather map of December 4, 1931, shows an area of low pressure extending over southern Visayas, Mindanao, and Palawan. The rapid drop of the barometer east of Samar early in the morning of December 5, left no doubt but that a typhoon had developed in the eastern sector of the depression and it was fast approaching Samar. Typhoon warnings were sent immediately to all the Provinces and stations likely to be affected, and, on account of the peculiar period of the milling season, to all the sugar centrals of Visayas. The typhoon moved so fast that shortly after noon of December 5, it passed south of and very close to Catbalogan, Samar, where the barometer dropped from 756.91 mm. at 8 a. m. to 734.67 mm. 18 minutes past noon. Government offices at

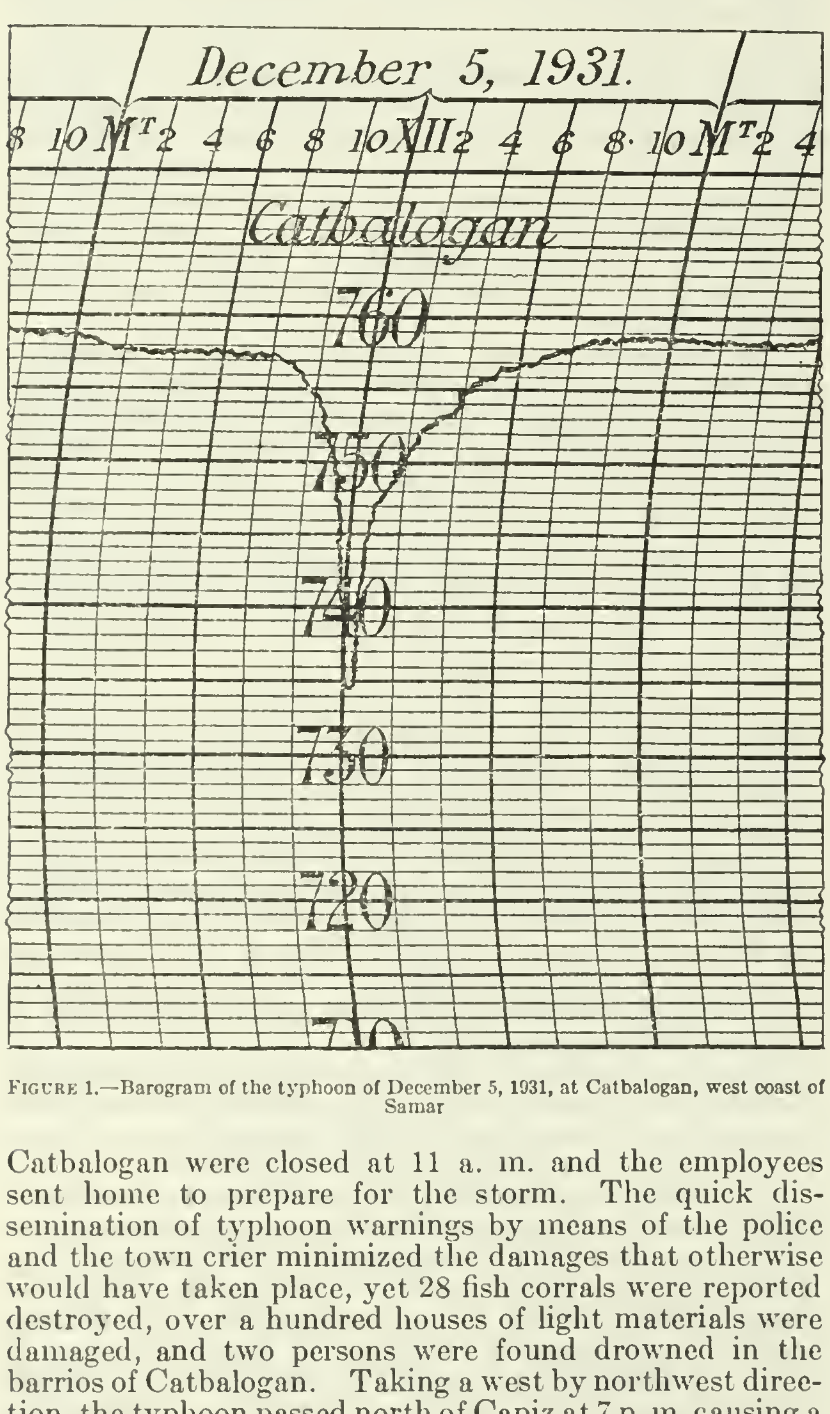


FIGURE 1.—Barogram of the typhoon of December 5, 1931, at Catbalogan, west coast of Samar

Catbalogan were closed at 11 a. m. and the employees sent home to prepare for the storm. The quick dissemination of typhoon warnings by means of the police and the town crier minimized the damages that otherwise would have taken place, yet 28 fish corrals were reported destroyed, over a hundred houses of light materials were damaged, and two persons were found drowned in the barrios of Catbalogan. Taking a west by northwest direction, the typhoon passed north of Capiz at 7 p. m. causing a barometric minimum of 744.66 mm. and southwesterly gusts of force 11. One hour and a half after midnight, the typhoon passed close to and north of the Culion Leper Colony and was located in the China Sea about 130 miles to the westward on the morning weather map of December 6.

The typhoon was treacherous on account of the high velocity of its translation and the narrowness of its diameter. The 530 kilometers that separated Catbalogan from Culion were covered by the typhoon in 13 hours and 15 minutes, giving a velocity of 40 kilometers, or almost 25 miles, per hour.

The narrowness of the storm's diameter is evident from the fact that, * * * although the wind was very strong in the proximity of the center, yet in some places like Culion and southern Mindoro, four hours before and after the barometric minimum the wind was no more than a gentle breeze with clear or partly cloudy sky. The motor boat *Siruma* was washed ashore and completely destroyed on the eastern coast of Sibuyan and the *Virginia*, on the western coast of Busuanga. The barogram from Catbalogan, presented herewith, shows the limited extent, but steepness of gradient, of the typhoon.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

Table 1 shows the average temperatures for the Caribbean Sea and the Straits of Florida for December of each year from 1919 to 1930, inclusive, and Table 2 summarizes the temperatures for December, 1930, in the same areas. The chart shows the number of observations taken in December, 1930, within each 1° square, and mean temperature data for subdivisions of the area considered.

The surface temperatures of the Straits of Florida fall rapidly during December, but the seasonal downward trend frequently is interrupted by alternations of warmer and cooler quarter-months, especially in the latter part of the month. This fluctuation of mean temperature is a winter condition, and is in contrast with the fairly steady and persistent drop of autumn. By the end of the month, the transition from autumn to winter is well advanced, and normal temperatures characteristic of winter prevail, with the water temperatures usually not far from the normal annual minimum.

During December the season has not progressed so far in the Caribbean, where autumn conditions still persist, as it has in the straits. This month is in the midst of the period of most rapid drop in normal temperature over all parts of the Caribbean Sea, where the winter season of relatively low temperatures, with little or no upward or downward trend, is delayed until late January and lasts until early March.

December, 1930, was the warmest December in the Caribbean during the term of years covered (1920–1930) and the coolest in the Straits of Florida. For this month as a whole nearly all parts of the Caribbean were unprecedentedly warm and *all* distinctly above their average temperatures for the 11-year period. The third quarter of this month was relatively the coolest, when the mean temperature of the Caribbean was a trifle below that of the same period in 1926. The other three quarters were record-breaking or record-equaling. In the Straits of Florida, only the first quarter of this month was near the seasonal average. The second, third, and fourth quarters were cooler than the hitherto coolest corresponding periods.

Current charts[1] indicate that the water flowing through the Yucatan Channel between November and January divides into three main branches. The weakest, in the

[1] Cf. Hydrographic Office of the Navy Department of the United States. Pilot Chart of the Central American Waters. Washington, D. C. Published monthly.

sense of the least rapid, makes, as does the main[2] flow in the summer and autumn months, the circuit of the Gulf, around the Sigsbee Deep. The stronger and principal winter branches take a more direct route to the straits. Here, the currents indicated on the Hydrographic Office Charts[1] show that, during the late autumn and early winter, one branch heads almost due north from the Yucatan Channel, and reaches a point about 200 miles south of Mobile Bay, where it turns sharply to the eastward, then south-southeastward into the straits. A second branch flows almost directly from the channel, around northern Cuba and through the straits, joining the first near Alligator Reef, off the extreme southeast Florida coast. Both these currents seem to be rapid enough to cause that surface water from the Yucatan Channel which takes these routes to start passing through the straits by December. Therefore, it is to be expected that the Caribbean will begin, at this time of the year, to show its maximum effect in warming the waters of the straits.

In view of this geographical distribution of currents the conditions in 1930, when the Caribbean was warm throughout the autumn and the straits extremely cool in December, would seem to indicate one or the other of the following alternatives:

(1) That the currents or the conditions affecting the surface temperatures in these regions were in some way abnormal at that time;

(2) That the variations of the surface temperatures of the Caribbean waters do not soon thereafter and directly correspondingly modify the surface temperatures in the straits.

Considerable evidence, which will be discussed at a later time, favors the first of these two alternatives. Hence we may presume that the surface temperatures which obtained late in 1930 in these regions probably were caused by the superposition of some infrequent (though not unprecedented) control or controls upon the continuous influences of the flow from the Caribbean.

During the year 1930 all months except January and February showed temperatures above the 11-year mean in the Caribbean. A run of 10 consecutive months of high temperatures is, however, not an unusual condition in this area. Records show that periods of above average or below average temperature, are likely to last for from one to three or more years.

[1] Cf. Hydrographic Office of the Navy Department of the United States. Pilot Chart of the Central American Waters. Washington, D. C. Published Monthly.
[2] Cf. Bucket Observations of Sea Surface Temperatures. Monthly Weather Review. Vol. 59 : 211.

The year 1930 may then be summarized as containing the beginning of a more or less extended period of high temperatures in this area and having one record-breaking month. Notwithstanding the exceedingly high temperature of its final month, this year as a whole was not as warm as some others of the preceding decade, being merely an ordinarily warm year.

The mean temperature for 1930 in the Straits of Florida approximated the 11-year average, but June and December of that year were the coolest of these respective months in the 11-year period considered. The principal positive deviations from average temperatures were in the early part of the year. The departures for the last three months were negative.

Table 1.—*Mean seo-surface temperotures in the Caribbean Sea and the Stroits of Florida for December, 1919–1930*

Year	Carribbean Sea		Straits of Florida	
	Number of observations	Mean (° F.)	Number of observations	Mean (° F.)
1919 [1]	134	80.2	14	76.4
1920	199	80.4	57	76.1
1921	211	79.8	67	76.7
1922	241	79.9	87	77.3
1923	238	79.6	103	76.0
1924	287	80.2	98	75.9
1925	349	80.8	120	76.6
1926	330	80.9	142	77.0
1927	386	80.5	117	76.5
1928	354	80.3	120	76.4
1929	564	80.1	138	76.5
1930	462	81.2	130	74.9
Mean (1920–1930)		80.3		76.3

[1] Not used in computations because of insufficient data available.

Table 2.—*Mean sea-surface temperatures* (°F.) *and number of observations, December, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	Dec. 1–7	92	81.7			36	76.7		
II	Dec. 8–15	137	81.4			30	74.6		
III	Dec. 16–23	114	80.8			29	75.2		
IV	Dec. 24–31	119	80.8			35	73.0		
	Month	462	81.2	+0.9	−0.8	130	74.9	−1.4	−3.3

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau th monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, wit dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated b the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and th greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations tha have 10 or more years of observations. Of course, the number of such records is smaller than the total number o stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1931

[For description of tables and charts, see REVIEW, January, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F	°F		°F			°F		In.	In.		In.		In.
Alabama	55.8	+8.6	3 stations	83	[1]10	Riverton	25	[1]15	8.90	+4.08	Millers Ferry	15.15	Union Springs	3.5
Arizona	40.3	−3.8	Granite Reef Dam	87	20	Fort Defiance	−26	14	1.58	+.32	Supai	4.98	2 stations	.1
Arkansas	48.7	+6.2	Pine Bluff	78	23	Lead Hill	17	15	7.79	+3.70	El Dorado	23.86	Gravette	.5
California	42.4	−2.6	San Jacinto	83	18	South Lake	−22	12	8.48	+4.24	Ben Lomond	30.37	Greenland Ranch	.0
Colorado	23.8	−.9	Las Animas	78	24	Hermit	−40	13	.58	−.42	Cumbres	4.55	7 stations	----
Florida	69.8	+10.0	Moore Haven	90	5	Hilliard	36	29	2.96	+.06	Pensacola	8.98	Coral Gables	.0
Georgia	56.8	+9.3	2 stations	86	[1]1	Clayton	19	27	7.02	+2.75	Dahlonega	17.32	Meldrim	1.0
Idaho	22.2	−2.6	Twin Falls Factory	58	24	Felt	−30	15	2.71	+.51	Deadwood	13.67	Cottonwood	.2
Illinois	39.8	+9.2	New Burnside	76	11	Freeport	7	8	2.95	+.80	Mount Carmel	5.52	Pearl	1.5
Indiana	40.4	+8.3	Princeton	76	11	Notre Dame	11	8	3.40	+.54	Princeton	6.73	Rochester	1.0
Iowa	34.1	+10.0	2 stations	61	18	Lake Park (near)	3	7	2.48	+1.34	Lacona	4.40	Waverly	.8
Kansas	38.9	+7.0	Ashland	75	23	St. Francis	2	15	.65	−.19	Atchison	3.09	Ulysses	.0
Kentucky	46.1	+8.6	2 stations	73	[1]11	2 stations	17	[1]2	5.51	+1.48	Burnside	8.12	Ashland	2.9
Louisiana	57.9	+5.8	Morgan City	86	13	Plain Dealing	29	4	10.53	+5.31	Calhoun	26.34	Port Eads	3.6
Maryland-Delaware	42.8	+7.4	La Plata, Md	72	19	Sines, Md	9	8	2.45	−.71	Friendsville, Md	5.04	Hancock (city), Md	1.7
Michigan	32.7	+7.5	Monroe	64	11	Mio	−13	8	2.01	−.07	Lapeer	4.79	Iron River	.4
Minnesota	24.9	+10.4	Morris	59	30	2 stations	−24	[1]6	.58	−.15	Fairmont	2.48	2 stations	T.
Mississippi	55.6	+7.4	Crystal Springs	87	11	Holly Springs	27	15	11.96	+6.69	Greenville	21.53	Macon	6.9
Missouri	42.7	+8.8	Marble Hill	80	30	Maryville	11	14	2.57	+.50	Caruthersville	9.32	Nevada	.4
Montana	24.4	+2.6	Melstone	67	18	Kinread	−30	12	.62	−.25	Heron	5.79	2 stations	T.
Nebraska	31.2	+5.3	Kimball	66	18	Gordon	−12	13	1.14	+.44	Falls City	4.24	Lexington	T.
Nevada	27.9	−4.6	Logandale	66	5	Millett	−28	[1]14	1.85	+.92	Marlette Lake	10.57	Mina	.3
New England	30.0	+3.4	Hartford, Conn	64	12	Enosburg Falls, Vt	−28	27	3.35	-------	Mays Mill, Vt	5.39	Bar Harbor, Me	.9
New Jersey	39.6	+6.8	Runyon	72	12	Runyon	7	28	2.27	−1.74	Chatham	3.24	Pemberton	1.5
New Mexico	31.6	−1.5	Hope	74	26	Dulce	−38	2	.90	+.16	Dulce	4.50	Colmor	----
New York	31.1	+4.5	Flushing	69	12	2 stations	−17	8	3.06	+.08	Gabriels	5.63	Chazy	.5
North Carolina	50.4	+7.9	Fayetteville	86	20	Altapass	14	16	6.91	+3.06	Rock House	17.88	Wilmington	2.6
North Dakota	21.0	+8.4	Cando	58	18	Park River	−21	4	.23	−.29	Ellendale	1.20	4 stations	----
Ohio	39.8	+8.6	3 stations	71	11	2 stations	11	8	3.52	+.67	Middleport	5.18	Montpelier	1.8
Oklahoma	44.7	+5.3	Poteau	77	12	Kenton	6	14	1.23	−.42	Idabel	6.04	Blackwell	.0
Oregon	30.7	−1.6	2 stations	67	[1]16	Seneca	−38	15	4.61	+.94	Gold Beach	23.66	Frenchglen	.3
Pennsylvania	38.1	+7.0	Hanover	70	12	Coudersport	−1	8	2.85	−.31	Elk Lick	5.49	Reading	1.2
South Carolina	53.5	+6.9	3 stations	85	[1]12	Santuck	20	27	7.14	+3.52	Caesars Head	16.41	Myrtle Beach	1.6
South Dakota	25.0	+5.2	Spearfish	68	[1]18	Pukwana	−17	13	1.06	+.48	Onaka	4.23	Britton	.1
Tennessee	49.7	+9.2	Newport	81	12	Rugby	19	16	8.78	+4.28	Covington	11.41	Bristol	4.9
Texas	50.5	+1.0	Riogrande	91	29	Romero	5	14	3.96	+1.77	Bronson	16.44	Follett	.3
Utah	21.2	−5.2	St. Georges	60	25	Woodruff	−29	15	1.59	+.32	Silver Lake	6.81	Antimony	.1
Virginia	46.1	+8.0	Diamond Springs	82	14	Dale Enterprise	14	16	2.95	−.36	Speers Ferry	6.93	Orange	.9
Washington	30.6	−1.7	Walla Walla (a)	62	19	Wilbur	−15	12	7.29	+1.95	Wynoochee Oxbow	36.00	Alpowa Ranch	1.2
West Virginia	42.0	+8.2	2 stations	75	11	2 stations	8	7	3.94	+.48	Morgantown	7.05	Brandywine	1.3
Wisconsin	30.4	+10.2	Racine	58	22	Rhinelander	−11	7	1.17	−.09	Beloit	2.80	Mellen	.1
Wyoming	20.9	+.3	Chugwater	71	18	2 stations	−36	15	.53	−.25	Beehler River	5.94	2 stations	----
Alaska (November)	20.4	+3.9	Bell Island	56	3	Fort Yukon	−41	17	2.75	+.31	Mile Seven (Cordova).	15.90	Akiak	.1
Hawaii	68.5	−1.4	Waipahu	89	15	Kanalohuluhulu	40	7	7.21	−2.42	Kawainui (upper)	30.40	Ka Lae	----
Porto Rico	74.6	+.2	San German	94	3	Guineo Reservoir	46	11	3.93	−.57	Rio Grande	11.92	Santa Rita	----

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1931*

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01 or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							33.1	+3.7										70	3.19	−0.2										6.6		
astport	76	67	85	29.86	29.95	−0.03	27.5	+1.2	49	4	35	5	21	20	31	26	22	77	2.37	−1.4	18	8,864	nw.	31	nw.	5	2	4	25	8.5	2.9	0.0
reenville, Me.	1,070	6	----	28.79	29.98	-----	21.6	-----	41	4	29	−7	21	14	30	----	----	----	3.40	-----	15	6,685	nw.	27	-----	26	6	5	20	----	24.5	0.0
ortland, Me.	103	82	117	29.88	30.01	−.02	31.8	+4.2	51	24	39	13	8	25	23	27	20	65	3.53	−.4	13	5,896	nw.	30	nw.	7	11	6	14	5.8	2.9	0.0
oncord	289	70	79	29.70	30.03	−.03	29.0	+2.2	56	12	38	5	9	20	32	----	----	----	4.70	+1.6	10	4,349	nw.	25	w.	7	12	3	16	5.8	2.2	0.0
urlington	403	11	48	29.60	30.07	+.02	26.4	+2.0	52	12	34	1	28	18	37	----	----	----	2.17	+.3	13	7,855	s.	39	s.	21	5	4	22	7.6	4.1	T.
orthfield	876	12	60	29.08	30.07	+.02	24.0	+3.6	52	12	34	−5	6	14	39	21	18	82	2.01	−.5	16	5,095	n.	26	n.	5	5	9	17	7.2	7.0	0.2
oston	125	106	165	29.89	30.03	−.02	36.6	+4.1	61	12	44	14	8	29	26	32	24	63	2.90	−.6	10	6,114	nw.	28	nw.	5	10	5	16	6.1	1.4	0.0
antucket	12	14	90	30.02	30.03	−.02	39.4	+3.6	55	22	46	19	8	33	24	36	31	73	4.05	+.3	12	11,148	nw.	40	sw.	7	6	4	21	7.4	T.	0.0
lock Island	26	11	46	30.01	30.04	−.02	39.6	+3.6	54	22	46	18	8	33	28	36	30	69	3.59	−.2	10	14,337	w.	55	w.	7	9	9	13	6.3	T.	0.0
ovidence	160	215	251	29.87	30.05	−.01	37.0	+5.4	57	12	45	14	8	29	31	32	25	61	3.20	−.2	11	8,792	nw.	46	nw.	14	11	7	13	5.4	.3	0.0
artford	159	122	----	29.88	30.06	−.01	35.7	+5.9	64	12	43	14	8	28	25	----	----	----	3.00	−1.0	9	-----	nw.	----	-----	----	11	4	16	6.2	1.6	0.0
ew Haven	106	74	153	29.96	30.08	+.01	37.6	+5.1	58	23	46	17	8	30	29	33	27	66	3.54	−.5	10	5,973	nw.	30	nw.	14	10	9	12	6.0	T.	0.0
iddle Atlantic States							42.9	+7.2										72	2 20	−1.1										6.4		
bany	97	107	115	29.98	30.10	+.02	33.1	+4.6	55	12	40	10	8	26	26	29	24	71	2.62	.0	9	5,135	s.	23	sw.	25	10	8	13	5.6	.5	0.0
nghamton	871	10	84	29.14	30.10	+.01	34.6	+6.4	56	24	42	12	8	27	27	----	----	----	2.25	−.1	15	4,255	nw.	25	nw.	7	5	3	23	7.7	3.2	T.
ew York	314	414	454	29.74	30.10	+.01	40.6	+5.6	66	12	48	19	8	33	23	36	29	66	2.22	−1.4	9	11,908	nw.	58	nw.	14	7	9	15	6.5	T.	0.0
llefonte	1,050	5	36	28.98	30.12	-----	35.6	-----	59	12	44	11	8	27	33	31	28	78	1.81	-----	11	-----	w.	48	se.	11	3	10	18	7.6	.2	T.
arrisburg	374	94	104	29.72	30.13	+.01	40.2	+7.5	62	12	47	22	8	33	23	35	28	66	1.70	−1.3	9	4,695	w.	38	w.	14	8	8	15	6.3	.8	0.0
iladelphia	114	123	367	30.01	30.14	+.03	44.2	+7.9	65	12	51	23	8	37	24	38	31	62	1.78	−1.6	7	8,939	nw.	44	w.	14	7	9	15	6.3	T.	0.0
eading	325	81	103	29.78	30.14	-----	40.1	+7.9	64	12	46	21	8	34	21	36	32	75	1.27	−2.3	7	4,052	w.	25	w.	14	8	8	15	6.5	.5	0.0
ranton	805	72	103	29.26	30.14	+.04	36.0	+5.3	59	12	44	15	8	28	28	33	29	76	1.35	−1.7	12	4,650	sw.	38	nw.	14	6	12	13	6.6	.9	0.0
lantic City	52	37	172	30.06	30.12	+.02	43.8	+7.4	67	12	52	21	8	36	26	39	34	70	2.57	−1.4	7	11,447	w.	49	w.	14	8	10	13	5.8	0.0	0.0
pe May	17	13	49	-----	-----	-----	44.4	+6.4	62	12	52	24	8	37	26	41	36	76	2.34	−1.4	6	-----	nw.	----	-----	----	7	11	13	----	T.	0.0
ndy Hook	22	10	55	30.07	30.09	-----	41.0	-----	59	12	47	22	8	35	20	37	33	75	1.62	−2.4	7	10,935	w.	49	nw.	14	7	8	16	6.3	T.	0.0
enton	190	159	183	29.91	30.12	-----	40.5	+6.1	67	12	48	20	8	32	23	36	30	68	2.36	−1.0	7	6,976	nw.	41	nw.	14	8	7	16	6.5	T.	0.0
ltimore	123	100	215	30.00	30.14	+.01	45.7	+8.5	70	12	53	26	8	38	25	39	33	64	2.20	−1.2	7	6,674	sw.	43	sw.	14	7	11	13	6.5	.7	0.0
ashington	112	62	85	30.02	30.15	+.02	44.2	+7.6	70	14	52	24	8	36	31	39	33	68	2.03	−1.3	9	4,220	nw.	34	nw.	14	6	9	16	6.6	1.0	0.0
pe Henry	18	8	54	30.13	30.15	-----	51.8	+8.1	77	13	59	33	16	44	25	46	42	75	2.05	−1.4	9	9,307	sw.	48	n.	7	5	15	11	6.2	.0	0.0
nchburg	681	153	188	29.42	30.18	+.01	47.3	+7.8	73	19	56	21	27	38	26	42	38	76	2.74	−.5	10	4,766	w.	42	nw.	25	9	8	14	6.0	.0	0.0
orfolk	91	170	205	30.07	30.17	+.04	51.9	+8.8	76	13	60	30	8	44	27	46	41	72	1.71	−1.6	9	8,583	w.	36	nw.	25	7	12	12	6.0	0.0	0.0
chmond	144	11	52	30.01	30.17	+.03	47.8	+8.0	76	19	58	25	8	38	32	42	38	76	2.52	−.8	9	4,841	sw.	27	nw.	25	7	12	12	6.0	1.0	0.0
ytheville	2,304	49	55	27.75	30.18	+.03	43.2	+7.9	69	13	51	18	27	35	27	39	36	81	4.18	+1.3	12	5,216	w.	27	e.	31	7	4	20	7.0	0.0	0.0
outh Atlantic States							55.8	+8.5										82	5.70	+2.3										6.4		
heville	2,253	89	104	27.80	30.20	+.04	47.4	+9.6	73	12	57	23	16	38	31	42	39	82	6.49	+3.3	14	5,806	nw.	33	e.	31	10	10	11	5.8	T.	0.0
arlotte	779	55	62	29.33	30.18	+.02	50.6	+7.6	79	20	59	28	8	42	27	46	43	84	11.24	+7.4	12	3,343	sw.	20	sw.	24	4	13	14	6.7	0.0	0.0
eensboro	886	6	56	29.21	30.19	-----	46.7	-----	77	20	57	21	3	37	30	41	39	85	5.35	-----	13	4,994	sw.	30	nw.	14	7	8	16	6.2	0.0	0.0
atteras	11	5	50	-----	30.16	+.03	56.2	+6.1	73	22	62	36	27	50	19	----	----	84	5.52	+1.3	8	9,113	ne.	35	nw.	26	12	6	13	----	0.0	0.0
leigh	376	103	146	29.77	30.18	+.03	51.2	+8.2	79	12	60	29	8	42	26	45	40	73	6.12	+2.5	12	5,464	sw.	28	nw.	14	8	9	14	6.1	0.0	0.0
ilmington	72	73	106	30.10	30.18	+.03	56.4	+7.3	80	20	66	31	27	47	31	51	48	79	2.64	−.1	13	5,676	sw.	28	nw.	28	12	6	13	5.5	0.0	0.0
arleston	48	11	92	30.12	30.16	+.01	61.3	+9.6	81	20	68	40	27	54	21	56	54	84	2.25	−.5	8	7,206	ne.	30	ne.	2	7	11	13	6.2	0.0	0.0
lumbia, S. C.	351	41	57	29.79	30.18	+.02	53.6	+6.4	81	20	62	32	8	45	35	48	44	78	6.46	+3.4	10	4,107	ne.	21	sw.	14	6	13	12	6.3	0.0	0.0
e West	711	10	55	29.41	30.20	-----	51.5	-----	79	20	60	30	8	43	27	----	----	----	11.68	-----	16	5,635	ne.	27	e.	31	4	9	18	7.0	0.0	0.0
eenville, S. C.	1,039	139	146	29.06	30.17	-----	51.2	+9.0	78	20	59	28	8	43	25	46	44	84	12.56	+7.7	15	5,517	ne.	30	ne.	3	5	10	16	6.3	0.0	0.0
gusta	182	62	77	29.96	30.16	.00	56.0	+7.9	80	13	65	31	27	47	35	50	47	82	5.35	+2.1	11	3,196	nw.	20	nw.	24	4	13	14	6.8	0.0	0.0
vannah	65	150	194	30.08	30.15	.00	62.8	+10.4	82	4	71	40	27	55	25	56	54	82	1.50	−1.4	11	7,263	ne.	26	ne.	2	7	8	16	6.7	0.0	0.0
ksonville	43	209	245	30.09	30.14	.00	67.6	+11.3	81	14	74	46	27	61	23	62	59	83	2.57	−.4	9	7,097	s.	28	sw.	4	5	11	15	6.8	0.0	0.0
Florida Peninsula							74.8	+8.3										82	2.24	+0.4										5.4		
y West	22	10	64	30.05	30.07	−.01	76.6	+6.3	83	9	81	65	28	73	12	71	69	81	4.04	+2.4	10	6,985	e.	20	s.	31	12	14	5	4.5	0.0	0.0
iami	25	124	168	30.08	30.11	.00	75.4	+7.4	82	5	79	60	29	72	18	69	67	78	1.49	−.2	9	6,803	e.	41	sw.	31	7	18	6	5.6	0.0	0.0
mpa	35	86	197	30.07	30.11	−.01	72.4	+11.3	86	1	80	53	27	64	24	66	65	87	1.20	−.9	4	6,511	s.	42	nw.	31	5	11	15	6.5	0.0	0.0
tusville	44	5	----	30.08	30.14	-----	72.6	-----	86	1	80	54	29	65	27	----	----	----	3.88	-----	9	-----	se.	----	-----	----	10	17	4	5.1	0.0	0.0
East Gulf States							57.7	+8.2										83	8.75	+3.9										7.1		
lanta	1,173	190	198	28.91	30.17	+.01	51.4	+6.7	74	12	59	31	8	44	29	48	45	83	12.07	+7.4	19	6,672	e.	31	e.	8	7	5	19	6.9	0.0	0.0
acon	370	78	87	29.76	30.17	+.01	55.3	+7.8	79	12	64	32	27	46	32	50	46	79	6.09	+2.1	15	3,793	n.	18	nw.	14	6	2	23	7.5	0.0	0.0
omasville	273	49	103	29.83	30.13	−.02	63.6	+11.1	81	11	72	42	26	55	27	58	55	82	7.81	+3.5	10	5,168	s.	27	nw.	31	3	11	17	7.2	0.0	0.0
alachicola	36	11	51	30.07	30.11	-----	66.0	-----	82	14	72	46	26	60	21	62	61	89	7.81	+2.7	7	6,326	se.	28	se.	8	4	8	19	7.0	0.0	0.0
nsacola	56	149	185	30.04	30.10	−.05	63.0	+9.0	76	23	69	44	26	57	23	60	58	84	8.98	+4.3	14	9,306	e.	46	w.	31	6	10	15	6.5	0.0	0.0
niston	741	9	57	-----	-----	-----	53.0	+8.8	76	11	61	32	5	45	31	----	----	----	10.96	+5.9	19	3,718	s.	24	sw.	8	4	10	17	----	0.0	0.0
rmingham	700	11	48	29.37	30.14	−.02	54.4	+8.0	79	13	62	33	15	47	33	50	47	82	8.33	+3.2	14	5,136	s.	28	se.	8	4	8	19	7.2	0.0	0.0
obile	57	125	161	30.03	30.09	−.06	61.3	+9.1	78	24	69	43	26	54	23	58	55	86	9.18	+4.2	15	6,588	s.	30	w.	31	4	8	19	7.4	0.0	0.0
ontgomery	223	100	112	29.89	30.14	−.02	57.5	+8.1	81	11	65	39	15	50	28	52	49	80	7.24	+2.4	17	4,475	e.	27	sw.	31	5	7	19	7.2	0.0	0.0
rinth	469	6	----	-----	-----	-----	52.8	-----	73	23	61	29	15	44	31	----	----	----	10.40	-----	17	-----	se.	----	-----	----	2	17	12	----	0.0	0.0
eridian	375	87	95	29.71	30.11	−.05	55.9	+8.2	81	11	64	35	5	48	29	51	48	82	9.16	+3.9	17	3,852	ne.	22	e.	8	7	5	19	7.0	0.0	0.0
cksburg	247	65	73	29.83	30.12	−.03	56.2	+6.2	79	12	64	36	15	49	26	51	47	78	8.76	+3.4	13	4,802	ne.	32	e.	8	5	10	16	7.2	0.0	0.0
w Orleans	53	76	84	30.02	30.07	−.06	63.0	+7.4	84	11	70	46	26	56	23	58	56	84	8.63	+3.8	16	4,547	ne.	22	e.	8	6	8	17	6.9	0.0	0.0
West Gulf States							53.4	+3.0										80	5.14	+2.2										6.6		
reveport	249	204	220	29.81	30.09	−.04	53.0	+3.9	77	23	60	36	15	46	31	49	45	80	10.43	+6.1	16	6,564	s.	33	w.	31	7	10	14	6.8	0.0	0.0
ntonville	1,303	11	44	28.66	30.05	−.08	45.5	+8.0	67	23	54	22	15	37	31	----	----	----	.59	-----	11	3,303	s.	17	sw.	11	14	4	13	----	0.0	0.0
rt Smith	457	79	94	29.58	30.07	−.06	48.3	+6.2	70	12	57	28	15	40	31	43	39	70	1.46	−1.3	13	4,511	e.	24	sw.	11	9	6	16	6.2	0.0	0.0
ttle Rock	357	136	153	29.72	30.10	−.04	49.8	+5.6	72	11	56	32	2	43	25	46	43	80	9.14	+5.0	18	5,203	sw.	24	s.	11	7	4	20	7.4	0.0	0.0
stin	605	136	148	29.43	30.06	-----	53.2	+2.2	76	23	62	30	18	44	34	48	45	78	4.24	+1.6	14	5,348	n.	28	nw.	31	8	8	15	6.4	0.9	0.0
ownsville	57	83	100	29.98	30.04	-----	61.8	+1.6	82	11	69	40	20	55	27	57	54	83	1.85	+.3	9	7,747	nw.	33	se.	29	5	9	17	6.9	0.0	0.0
rpus Christi	20	11	78	30.04	30.06	−.06	59.0	+1.0	79	30	65	40	20	52	29	55	52	83	1.77	+.3	9	7,426	nw.	32	s.	10	4	9	18	7.1	0.0	0.0
llas	512	220	227	29.50	30.06	-----	50.8	-----	73	23	58	32	14	44	31	----	----	----	2.81	+.4	14	8,027	se.	44	w.	31	10	5	16	6.2	0.0	0.0
rt Worth	670	106	114	29.34	30.06	−.06	51.0	+3.5	72	28	59	32	15	43	28	45	41	73	2.73	+.9	8	5,127	sw.	26	nw.	31	7	8	16	6.5	0.0	0.0
lveston	54	106	114	30.02	30.08	−.04	57.4	+1.0	75	13	62	41	20	52	26	54	52	87	7.81	+4.1	14	7,745	se.	26	nw.	14	7	7	17	6.7	0.0	0.0
uston	138	292	314	29.92	30.07	-----	56.0	+1.6	80	22	63	39	20	49	32	----	----	----	6.01	+1.8	16	8,756	s.	30	s.	10	5	11	15	6.9	0.0	0.0
lestine	510	64	72	29.55	30.09	−.03	52.0	+2.1	79	23	60	32	18	44	32	48	45	81	7.54	+3.9	17	4,993	ne.	22	ne.	1	8	7	16	6.7	0.0	0.0
rt Arthur	34	58	66	30.01	30.05	-----	56.4	-----	77	13	63	38	4	50	28	----	----	----	9.02	+3.8	14	5,988	s.	26	ne.	7	5	9	17	7.1	0.0	0.0
n Antonio	693	242	301	29.32	30.05	−.06	55.2	+1.5	79	27	63	34	17	47	27	50	45	75	2.79	+1.2	13	7,464	n.	31	nw.	30	7	11	13	6.2	0.0	0.0
ylor	571	38	51	29.49	30.10	−.01	52.2	+1.6	78	23	61	31	18	43	33	----	----	----	4.30	+2.0	11	5,107	n.	25	s.	29	7	15	9	5.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							44.9	+8.4										80	5.15	+1.7										7.5		
Chattanooga	762	190	215	29.33	30.16	0.00	50.7	+7.4	72	12	57	35	16	44	30	47	43	77	11.36	+6.2	16	4,882	ne.	28	nw.	14	6	9	16	6.9	0.0	0.
Knoxville	995	102	111	29.10	30.17	+.01	49.2	+8.9	74	12	56	30	27	42	25	46	43	83	7.92	+3.4	17	3,994	ne.	21	sw.	24	4	9	18	7.5	T.	0.
Memphis	399	78	86	29.68	30.11	−.04	51.6	+8.0	74	20	58	31	2	45	26	48	46	83	10.19	+5.7	17	4,616	e.	26	sw.	29	9	6	16	6.4	0.0	0.
Nashville	546	168	191	29.57	30.16	+.01	50.2	+9.2	69	12	57	30	2	44	24	47	44	82	6.33	+2.1	14	5,946	s.	36	w.	13	5	5	21	7.6	0.0	0.
Lexington	989	193	230	29.09	30.18	+.04	44.4	+8.6	66	11	51	25	2	38	25	----	----	----	5.84	+2.1	19	8,718	sw.	35	sw.	11	4	4	23	8.0	0.0	0.
Louisville	525	188	234	29.57	30.17	+.03	45.1	+7.5	69	11	52	28	2	39	23	42	39	81	3.99	+.2	13	6,070	s.	32	w.	24	5	4	22	7.9	0.0	0.
Evansville	431	76	116	29.66	30.14	+.01	45.8	+8.7	73	11	52	28	2	40	23	43	40	81	4.87	+1.3	16	5,363	e.	29	sw.	11	4	9	18	7.2	0.0	0.
Indianapolis	822	194	230	29.22	30.13	+.01	41.2	+9.0	66	11	47	23	8	35	21	38	34	79	4.41	+1.4	12	7,277	sw.	30	w.	24	6	8	17	6.8	T.	0.
Royal Center	736	11	55	29.30	30.12	-----	37.8	-----	62	11	44	18	8	32	24	----	----	----	2.16	−.5	11	7,141	sw.	35	e.	31	7	6	18	7.1	0.2	0.
Terre Haute	575	96	129	29.50	30.13	-----	41.9	-----	67	11	48	26	2	36	22	39	36	83	4.28	+1.4	11	5,638	s.	26	sw.	11	8	6	17	6.6	T.	0.
Cincinnati	627	11	51	29.46	30.16	+.03	42.5	+9.1	70	11	50	22	2	35	24	39	36	82	3.35	+.4	14	4,803	sw.	24	w.	14	4	4	23	7.8	0.0	0.
Columbus	822	216	230	29.25	30.14	+.02	41.1	+8.7	66	11	48	21	8	34	23	38	34	80	3.29	+.6	10	7,209	sw.	37	w.	14	4	7	20	7.7	T.	0.
Dayton	899	137	173	29.17	30.15	-----	41.4	+8.8	67	11	48	22	8	35	21	38	35	82	4.29	+1.5	11	5,518	sw.	26	w.	24	4	9	18	7.6	T.	0.
Elkins	1,947	59	67	28.09	30.20	+.08	40.6	+7.9	67	11	50	13	8	31	34	37	34	82	3.81	+.4	16	4,070	w.	27	w.	14	3	4	24	8.5	.3	0.
Parkersburg	637	77	82	29.51	30.18	+.04	43.1	+7.9	66	11	51	21	8	36	28	39	34	75	3.54	+.5	15	3,767	se.	27	nw.	14	4	4	23	8.1	0.0	0.
Pittsburgh	842	353	410	29.22	30.15	+.04	41.5	+7.3	62	13	48	21	8	35	24	38	33	75	2.94	+.1	13	7,386	w.	36	w.	14	3	6	22	8.0	T.	0.
Lower Lake Region							35.8	+6.7										78	2.71	0.0										7.7		
Buffalo	767	247	280	29.23	30.08	+.02	35.6	+5.8	56	24	42	15	8	29	24	32	29	80	2.08	−1.3	15	12,946	w.	62	w.	7	3	6	22	7.7	2.9	0.
Canton	448	10	61	29.56	30.06	-----	24.8	+2.1	50	12	34	−5	8	16	33	----	----	----	2.85	+.2	15	6,025	sw.	35	sw.	17	5	6	20	7.3	9.9	.
Ithaca	836	74	100	29.16	30.09	-----	35.2	+6.2	55	12	43	14	27	28	26	31	27	75	3.06	+.7	17	7,293	nw.	33	nw.	7	3	4	24	8.3	2.1	0.
Oswego	335	71	85	29.71	30.09	+.03	33.2	+4.2	55	24	40	11	8	26	28	30	26	76	2.65	−.8	15	8,014	s.	33	w.	7	2	3	26	8.7	3.0	T.
Rochester	523	86	102	29.52	30.10	+.04	35.2	+5.9	56	12	42	12	8	29	27	31	27	75	2.74	-----	15	6,435	w.	36	w.	17	4	6	21	8.0	5.0	T.
Syracuse	596	65	79	29.44	30.10	+.03	34.2	+5.9	56	24	41	14	8	27	30	----	----	----	2.60	−.5	14	4,948	w.	26	nw.	7	2	14	15	7.2	5.2	0.
Erie	714	130	166	29.32	30.11	+.04	38.4	+6.5	60	24	44	23	27	33	22	35	31	77	2.80	-----	11	10,592	sw.	37	w.	7	6	6	19	7.2	.2	0.
Cleveland	762	267	337	29.27	30.11	+.02	40.2	+9.0	64	11	46	24	8	34	24	36	31	73	2.65	+.2	9	10,212	sw.	48	w.	7	2	5	24	8.5	T.	0.
Sandusky	629	65	67	29.41	30.11	+.02	38.9	+7.7	64	11	45	19	8	33	22	----	----	----	2.37	+.1	9	6,316	sw.	27	nw.	7	4	5	22	7.9	.2	0.
Toledo	628	208	243	29.43	30.13	+.05	38.2	+7.8	64	11	44	18	8	32	23	35	31	78	3.22	+.9	8	9,134	sw.	38	sw.	24	7	6	18	6.9	T.	0.
Fort Wayne	856	100	119	29.18	30.12	-----	38.2	+10.9	63	11	44	19	8	33	20	36	33	85	2.88	+.3	14	6,585	sw.	30	sw.	24	7	3	21	7.5	T.	0.
Detroit	730	218	258	29.31	30.12	+.05	37.2	+7.9	62	11	43	19	8	32	20	34	31	81	2.66	+.3	10	7,543	sw.	32	sw.	11	4	6	21	7.7	1.3	0.
Upper Lake Region							32.8	+8.1										81	1.86	−.3										7.5		
Alpena	609	13	89	29.40	30.09	+.07	31.2	+6.4	52	18	37	6	8	25	22	29	25	78	2.23	+.2	10	7,279	nw.	32	e.	31	4	8	19	7.7	11.6	2.
Escanaba	612	54	60	29.40	30.09	+.06	30.8	+8.4	50	18	36	9	8	26	27	29	25	79	1.16	−.6	7	6,646	sw.	33	n.	4	5	5	21	7.5	5.1	0.
Grand Haven	632	54	89	29.40	30.10	+.05	35.3	+6.0	51	11	41	12	8	30	22	33	31	85	2.89	+.4	9	8,065	sw.	40	w.	7	3	4	24	8.4	6.3	.
Grand Rapids	707	70	244	29.32	30.11	+.03	35.8	+7.3	55	11	41	17	5	30	23	33	30	81	2.64	+.1	9	8,043	sw.	47	sw.	11	4	4	23	8.2	7.0	0.
Houghton	668	64	99	29.31	30.06	+.04	29.8	+8.0	45	22	34	9	8	25	25	----	----	----	.77	−2.3	7	6,264	w.	36	w.	6	1	7	23	8.0	4.8	0.
Lansing	878	6	88	29.13	30.10	-----	33.6	+6.4	57	11	40	12	8	28	22	32	31	92	3.79	+1.7	11	6,231	sw.	31	sw.	11	5	6	20	7.5	5.5	0.
Ludington	637	60	66	29.38	30.39	-----	34.8	+6.4	48	11	40	14	8	30	16	32	29	81	2.22	−.3	13	7,749	e.	37	sw.	2	4	12	15	6.8	5.0	T.
Marquette	734	77	111	29.24	30.06	+.04	31.7	+9.1	53	18	36	10	7	27	24	29	25	78	1.09	−1.6	10	6,742	w.	35	sw.	8	1	6	24	8.5	3.3	0
Port Huron	638	70	120	29.38	30.09	+.03	35.2	+7.6	59	11	41	14	8	30	21	32	30	82	1.82	−.2	13	7,569	w.	36	nw.	7	4	9	18	7.3	3.0	0.
Sault Sainte Marie	614	11	52	29.37	30.09	+.09	28.1	+7.6	44	18	34	2	5	22	30	27	23	80	1.86	−.5	14	5,562	se.	32	nw.	7	5	7	19	7.6	8.5	0.
Chicago	673	7	131	29.37	30.12	+.04	38.4	+9.6	58	11	43	20	7	34	20	35	32	80	2.28	+.2	12	7,307	sw.	30	sw.	11	8	7	16	6.5	5.6	0.
Green Bay	617	109	141	29.40	30.08	+.04	32.0	+9.7	50	18	37	6	7	27	21	29	26	79	1.10	−.6	8	7,191	sw.	34	ne.	24	6	4	21	7.7	2.8	0.
Milwaukee	681	125	221	29.34	30.10	+.04	36.2	+10.1	53	22	42	11	7	31	23	33	29	79	1.85	+.1	8	9,540	w.	33	e.	31	6	6	19	7.1	5.3	.
Duluth	1,133	5	47	28.79	30.05	.00	26.6	+10.7	48	18	33	−6	7	21	30	25	22	83	.32	−.8	5	8,482	w.	38	ne.	30	9	3	19	6.8	3.0	0.
North Dakota							21.5	+9.1										87	.49	−.1										5.9		
Moorhead	940	50	58	29.00	30.06	−.02	21.2	+9.7	40	18	28	−12	7	14	33	20	19	91	.21	−.5	4	5,201	s.	20	s.	20	5	8	18	7.3	3.0	2.6
Bismarck	1,674	8	57	28.18	30.03	−.05	21.4	+6.7	44	22	30	−9	13	13	32	19	17	85	.53	-----	5	4,104	e.	21	se.	7	13	8	10	4.9	7.4	4.2
Devils Lake	1,478	11	44	28.39	30.03	−.03	20.0	+10.5	38	2	28	−10	7	13	33	19	18	92	.09	−.4	4	5,878	s.	21	nw.	6	4	12	15	6.8	1.2	1.1
Ellendale	1,457	10	56	28.43	30.05	-----	20.6	-----	45	18	29	−8	14	12	32	----	----	----	1.20	+.7	9	7,584	nw.	25	e.	29	8	10	13	5.9	11.4	10.2
Grand Forks	833	12	67	-----	-----	-----	19.6	-----	38	18	27	−15	7	13	32	18	----	----	.14	-----	3	-----	se.	28	nw.	6	5	10	16	----	2.3	10.8
Williston	1,878	41	48	27.95	30.00	−.06	23.4	+9.6	47	25	32	−8	12	14	29	20	17	79	.40	−.2	2	3,994	sw.	25	se.	21	13	8	10	4.6	4.3	1.7
Upper Mississippi Valley							37.1	+10.3										82	2.25	+0.6										6.8		
Minneapolis	918	102	208	29.03	30.04	-----	30.0	+10.4	48	22	36	−1	7	24	24	----	----	----	.71	−.3	8	7,157	se.	31	e.	29	7	6	18	6.7	3.5	T.
St. Paul	837	114	149	29.13	30.06	−.02	29.8	+10.8	47	19	36	0	7	24	26	----	----	----	.77	−.3	8	5,579	s.	26	nw.	6	9	5	17	6.6	4.8	.2
La Crosse	714	11	48	29.29	30.08	.00	32.6	+10.3	53	18	38	6	7	27	25	30	27	83	2.20	+.9	12	3,355	s.	19	sw.	2	6	4	21	7.3	6.4	2.0
Madison	974	70	78	29.01	30.10	+.02	33.0	+10.2	51	18	38	9	7	28	22	31	28	83	1.64	-----	9	6,167	sw.	31	ne.	31	6	5	20	7.1	4.8	1.1
Wausau	1,247	4	62	28.71	30.08	-----	28.0	-----	45	18	34	−1	7	22	25	----	----	----	1.28	−.2	8	4,354	w.	24	w.	6	7	3	21	7.4	3.7	0.
Charles City	1,015	10	51	28.98	30.09	−.01	32.0	+11.6	48	18	38	9	7	26	22	29	27	85	2.22	+.9	12	4,762	se.	24	ne.	30	10	3	18	6.5	4.4	2.0
Davenport	606	118	143	29.42	30.10	.00	37.1	+10.0	57	18	43	19	14	32	25	34	31	80	2.68	+1.2	12	7,005	sw.	38	ne.	31	6	7	18	6.9	6.7	.1
Des Moines	861	5	99	29.15	30.08	−.03	35.8	+9.8	55	18	42	14	14	30	26	33	31	85	3.72	+2.5	14	6,523	se.	28	n.	31	8	2	21	7.0	5.7	.8
Dubuque	700	81	96	29.32	30.10	.00	35.2	+10.5	54	18	40	15	7	30	25	32	29	80	1.51	+.1	11	3,886	se.	19	ne.	31	7	4	20	7.1	5.7	2.8
Keokuk	614	64	78	29.42	30.11	−.01	39.6	+10.0	60	18	46	20	14	33	24	36	33	81	2.01	+.6	12	4,737	sw.	21	e.	31	9	3	19	6.6	3.5	0.0
Cairo	358	87	93	29.73	30.12	−.03	47.8	+10.0	73	11	54	27	15	42	23	45	41	80	4.15	+.8	11	5,259	ne.	25	s.	11	4	9	18	7.4	.0	0.0
Peoria	609	11	45	29.44	30.12	+.01	38.6	+10.5	57	11	45	21	2	32	25	36	33	85	2.26	+.5	12	4,457	sw.	21	ne.	31	10	4	17	6.4	4.9	0.0
Springfield, Ill	636	5	191	29.41	30.10	−.02	41.0	+9.3	61	11	47	27	8	35	22	38	35	84	2.80	+.6	12	8,226	s.	33	s.	10	6	9	16	6.8	1.0	0.0
Hannibal	534	74	109	29.52	30.10	−.02	41.6	+10.1	62	18	48	23	14	35	29	----	----	----	2.49	+1.0	12	5,218	sw.	26	ne.	31	10	6	15	6.1	4.0	0.0
St. Louis	568	265	303	29.48	30.10	−.03	45.2	+10.5	66	23	52	30	14	39	23	40	36	75	3.28	+1.1	10	7,262	s.	28	sw	11	7	7	17	6.7	.0	0.0
Missouri Valley							35.5	+7.8										82	1.92	+.9										5.6		
Columbia, Mo	784	6	84	29.24	30.09	−.03	43.4	+10.2	65	18	51	25	14	36	25	----	----	----	2.52	+.7	11	4,715	sw.	20	nw.	24	6	12	13	6.3	1.6	0.0
Kansas City	963	161	181	29.02	30.08	+.04	42.5	+10.0	66	30	50	24	14	36	21	39	35	79	2.54	+1.2	11	5,580	sw.	28	sw.	23	8	12	11	5.8	2.4	0.0
St. Joseph	967	11	49	29.00	30.06	-----	40.0	-----	61	19	48	19	14	32	26	36	34	83	3.38	+2.4	11	5,156	se.	23	nw.	11	13	5	13	5	3.9	1.4
Springfield, Mo	1,324	98	104	28.64	30.07	−.06	44.8	+8.6	69	23	52	26	14	37	25	40	35	75	1.65	−.7	8	6,293	se.	24	se.	26	13	6	12	5.1	0.0	0.0
Iola	984	11	50	29.00	30.07	−.05	42.4	+8.5	64	29	51	21	14	34	29	----	----	----	.68	−.7	5	3,310	s.	16	s.	29	12	6	13	5.4	T.	0.0
Topeka	987	92	107	-----	-----	-----	41.0	+9.0	63	19	49	22	14	33	25	----	----	----	1.48	+.5	7	5,208	sw.	31	ne.	31	11	5	15	5.5	1.3	0.0
Lincoln	1,189	11	81	28.75	30.06	−.06	37.0	+9.4	57	25	44	18	1	30	24	34	31	84	2.26	+1.5	7	6,008	s.	24	n.	31	10	5	16	6.0	6.6	6.5
Omaha	1,105	115	122	28.85	30.07	−.04	37.0	+10.6	57	18	43	19	14	31	24	34	30	80	3.33	+2.4	9	4,510	sw.	21	ne.	31	12	3	16	5.7	3.8	3.0
Valentine	2,598	47	54	27.26	30.07	−.03	26.8	+2.2	59	28	38	−6	13	16	32	23	20	82	.61	-----	4	4,537	w.	20	e.	29	11	8	12	5.5	5.9	4.2
Sioux City	1,135	94	164	28.80	30.05	−.07	32.3	+9.2	53	18	38	10	14	26	25	30	27	83	1.83	+.9	8	7,453	s.	30	s.	8	9	7	15	6.0	1.4	1.1
Huron	1,306	59	74	28.61	30.07	−.03	23.8	+5.1	45	26	32	−7	14	16	29	22	20	88	2.15	+1.6	8	5,225	se.	22	se.	7	15	4	12	4.9	11.4	10.0
Pierre	1,572	70	75	28.32	30.05	−.05	24.8	+3.0	50	28	33	−5	14	17	32	22	19	81	.88	+.4	4	3,804	e.	24	ne.	6	12	10	9	5.0	7.9	7.1
Yankton	1,233	49	57	28.71	30.08	−.03	30.0	+7.2	53	22	36	8	7	24	26	----	----	----	1.67	+.8	6	4,273	w.	19	e.	30	13	3	15	5.5	7.5	6.7

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1931*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01 or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							24.9	+1.1										76	0.51	−0.3										5.3		
illings	3,140	5	-----	-----	-----	-----	28.6	-----	58	18	41	−2	12	16	37	-----		-----	.06	-----	2	-----	nw.				19	7	5	-----	1.0	0.0
avre	2,505	11	67	27.25	29.97	−0.08	23.4	+3.0	52	24	33	−17	12	14	35	21	18	84	.34	−.3	5	6,320	sw.	28	sw.	24	9	11	11	5.4	7.1	.3
elena	4,124	89	113	25.71	30.03	−.10	25.9	+1.7	54	18	33	1	1	18	29	22	16	68	.16	−.6	5	3,983	sw.	35	sw.	27	5	13	13	6.5	2.5	1.0
alispell	2,973	48	56	26.88	30.03	−.04	25.6	+.7	46	18	31	4	14	20	21	24	23	90	1.72	+.3	14	2,279	nw.	17	se.	28	1	5	25	8.8	16.4	10.8
iles City	2,371	48	55	27.42	30.07	−.03	22.1	+1.1	45	29	33	−12	12	12	31	20	18	87	.55	−.1	4	2,493	s.	21	nw.	29	13	11	7	4.5	6.5	5.0
apid City	3,259	50	58	26.54	30.06	−.03	31.6	+4.7	59	21	42	7	13	21	30	26	20	70	.62	+.2	4	3,644	w.	23	w.	21	11	11	9	4.8	6.0	5.2
eyenne	6,088	84	101	23.92	30.04	−.05	32.6	+4.1	67	18	44	3	12	21	40	24	14	50	.17	−.4	2	7,899	w.	40	nw.	29	15	8	8	4.2	2.3	1.8
ander	5,372	60	68	24.59	30.22	−.07	13.2	−7.2	50	21	24	−18	13	2	38	10	8	85	T.	−.7	0	1,768	sw.	31	sw.	21	22	8	1	2.4	.1	2.0
eridan	3,790	10	47	26.01	30.06	-----	23.3	-----	48	28	36	−3	31	11	39	18	14	77	.19	−.4	3	1,675	s.	22	nw.	29	13	13	5	4.1	3.5	2.8
ellowstone Park	6,241	11	48	23.82	30.05	−.11	21.5	−.1	49	18	29	−6	14	14	26	18	14	72	1.14	−.4	16	5,347	s.	29	sw.	21	6	7	18	7.1	19.6	15.4
orth Platte	2,821	11	51	27.04	30.07	−.03	28.6	+1.9	56	22	39	2	14	18	32	24	21	82	.15	−.4	2	3,760	w.	27	n.	30	12	7	12	5.1	.9	.8
Middle Slope							39.0	+5.6										69	.53	−.3										4.8		
enver	5,292	106	113	24.66	30.03	−.05	35.8	+3.5	64	17	46	8	13	25	34	27	15	46	.03	−.7	2	4,149	s.	22	n.	30	17	12	2	3.4	.8	0.0
eblo	4,685	80	86	25.25	30.05	−.03	33.2	+1.7	60	28	48	3	14	18	44	26	17	57	.02	−.5	1	3,833	nw.	33	w.	29	16	13	2	3.5	.2	0.0
oncordia	1,392	50	58	28.56	30.08	−.03	38.9	+8.2	58	25	47	21	1	31	25	34	32	87	.91	+.3	7	4,422	sw.	27	s.	26	13	9	9	4.6	1.2	.4
odge City	2,509	88	100	27.41	30.07	−.03	38.8	+6.2	67	22	49	17	14	29	32	33	28	74	.47	−.1	6	7,857	nw.	44	n.	31	16	5	10	4.5	.6	.5
ichita	1,358	139	158	28.59	30.05	−.06	42.1	+7.5	63	29	49	23	14	35	24	38	33	73	.69	−.3	7	6,733	s.	32	s.	26	10	6	15	6.2	T.	T.
lahoma City	1,214	10	47	28.76	30.06	−.05	45.6	+6.3	67	29	53	25	14	38	24	40	36	77	1.08	−.4	9	5,476	s.	22	nw.	13	7	9	15	6.5	T.	0.0
Southern Slope							44.0	−.1										73	1.64	+.7										5.6		
ilene	1,738	10	52	28.24	30.08	−.03	46.6	+.6	71	12	55	26	15	38	29	41	37	76	1.96	+.6	7	5,435	s.	30	nw.	31	10	4	17	6.3	6.5	0.0
narillo	3,676	10	49	26.26	30.06	−.03	40.3	+3.3	68	28	49	20	14	31	29	33	27	69	1.24	+.4	6	5,971	sw.	35	w.	30	10	6	15	5.7	11.2	0.0
l Rio	944	64	71	29.05	30.05	−.05	51.5	−.7	76	12	61	31	17	42	32	47	43	78	1.54	+.8	8	4,506	nw.	27	nw.	13	9	9	13	5.8	0.0	0.0
swell	3,566	75	85	26.40	30.10	+.03	37.5	−3.7	67	26	49	4	3	26	34	31	25	69	1.80	+1.1	6	3,845	n.	35	nw.	30	13	8	10	4.7	16.2	0.0
Southern Plateau							39.1	−2.6										62	.75	+.1										3.7		
Paso	3,778	152	175	26.22	30.08	+.05	43.8	−1.1	65	26	54	23	31	33	33	36	27	58	.30	−.2	6	5,909	nw.	37	w.	10	16	9	6	3.8	3.8	0.0
uquerque	4,972	51	66	25.08	30.11	-----	33.7	-----	55	22	45	13	14	23	32	27	19	59	.07	-----	1	3,213	ne.	29	w.	10	15	9	7	3.9	T.	0.0
nta Fe	7,013	38	53	23.21	30.13	+.07	27.7	−3.0	54	19	38	0	13	17	30	22	16	64	.50	−.2	4	3,858	n.	25	n.	30	15	7	9	4.4	6.1	.6
agstaff	6,907	10	59	23.31	30.09	+.03	22.8	−5.6	52	19	37	−19	13	9	49	20	-----	83	2.39	-----	8	-----	sw.	26	n.	16	11	12	8	-----	26.0	5.5
oenix	1,108	10	107	28.87	30.04	.00	49.7	−2.3	70	24	62	28	16	38	36	42	33	58	.75	−.2	3	2,809	e.	18	w.	12	17	8	6	3.6	0.0	0.0
ma	141	9	54	29.91	30.06	+.01	53.2	−2.0	70	19	64	36	4	42	29	43	32	49	.59	+.1	2	3,577	n.	25	ne.	6	20	9	2	2.7	0.0	0.0
lependence	3,957	6	27	25.98	30.09	−.03	37.6	−1.7	68	21	50	14	13	26	38	29	-----	-----	1.63	+.8	5	-----	nw.	-----	-----	-----	13	8	10	-----	0.0	0.0
Middle Plateau							25.1	−5.1										76	1.19	+0.2										5.6		
no	4,532	74	81	25.41	30.05	−0.10	31.0	−2.7	62	18	41	2	15	21	34	27	22	71	2.19	+1.2	12	3,241	se.	32	se.	26	8	7	16	6.0	7.2	T.
nopah	6,090	12	20	-----	-----	-----	26.8	-----	49	19	32	7	14	21	24	23	18	69	.59	-----	5	-----	se.	-----	-----	-----	-----	-----	-----	-----	0.0	0.0
nnemucca	4,344	18	56	25 60	30.10	−.08	26.9	−3.1	52	7	37	−7	15	16	31	23	20	79	1.17	+.1	12	5,061	ne.	27	s.	28	10	6	15	5.8	5.9	0.8
odena	5,473	10	43	24.62	30.17	+.05	19.0	−9.1	44	20	32	−17	13	6	39	17	14	86	.77	−.1	12	5,698	w.	32	nw.	28	10	7	14	5.6	11.9	4.6
t Lake City	4,360	163	203	25.66	30.14	−.01	27.9	−4.0	53	25	35	5	16	21	28	25	20	71	1.42	0.0	12	3,914	s.	28	se.	25	11	6	14	5.7	19.5	3.5
and Junction	4,602	60	68	25.46	30.18	+.08	20.8	−6.7	42	28	31	−9	16	10	36	18	16	83	.42	−.2	6	2,696	nw.	22	s.	29	12	10	9	4.7	3.8	0.0
Northern Plateau							28.1	−3.3										83	2.48	+.8										7.7		
ker	3,471	48	53	26.42	30.11	−.05	23.4	−3.9	41	24	31	−3	15	16	23	21	18	76	2.03	+.3	20	4,040	se.	27	sw.	27	7	2	22	7.4	19.4	8.1
se	2,739	79	87	27.21	30.16	−.04	28.6	−3.5	51	24	35	2	16	22	20	26	22	79	1.83	+.3	17	3,413	se.	25	se.	28	5	3	23	8.0	11.4	4.9
viston	757	40	48	29.22	30.05	−.08	33.8	−1.9	56	24	39	13	1	28	25	-----	-----	-----	1.92	+.4	13	2,386	e.	17	ne.	6	5	5	21	7.4	5.0	.1
atello	4,477	60	68	25.48	30.17	−.02	23.7	−4.0	48	21	32	−13	15	16	31	22	18	79	1.09	−.1	14	5,434	se.	36	s.	21	5	9	17	6.8	13.3	3.0
co	416	5	33	-----	-----	-----	27.2	-----	50	24	34	3	15	20	26	-----	-----	92	2.06	-----	17	3,520	nw.	-----	-----	-----	5	4	22	-----	4.4	2.3
kane	1,929	101	110	27.92	30.02	−.06	29.2	−1.3	49	19	35	5	15	24	22	28	27	88	3.88	+1.7	22	2,755	s.	22	sw.	7	3	7	21	8.1	18.4	4.1
lla Walla	991	57	65	28.92	30.02	−.10	33.1	−2.4	62	19	40	10	14	26	32	30	27	82	2.84	+.8	13	2,818	w.	26	se.	23	2	5	24	8.6	9.6	4.0
kima	1,076	58	67	28.84	30.03	-----	24.8	−5.9	45	24	31	−2	15	18	23	24	22	87	3.75	+2.4	17	1,476	se.	15	s.	24	4	9	18	7.6	29.9	16.1
orth Pacific Coast Region							41.8	−0.4										84	7.64	+.8										8.6		
th Head	211	11	56	29.61	29.84	−.19	42.2	−1.9	50	19	46	34	14	38	11	41	38	87	11.91	+2.4	28	14,364	se.	72	s.	17	1	3	27	8.9	T.	0.0
t Angeles	29	8	53	-----	29.83	-----	40.3	-----	55	17	45	28	14	35	17	-----	-----	-----	2.57	−2.2	22	3,205	s.	24	e.	26	0	12	19	-----	.5	0.0
ttle	125	215	250	29.73	29.86	−.15	41.8	+.1	55	19	46	30	15	38	15	39	36	78	6.54	+.9	26	6,039	se.	37	s.	7	1	8	22	8.2	T.	0.0
oma	194	172	201	29.65	29.86	−.15	41.4	+.8	56	19	46	27	1	36	17	-----	-----	-----	6.88	+.2	23	4,715	s.	37	s.	7	0	8	23	8.5	T.	0.0
oosh Island	86	9	53	29.68	29.78	−.18	42.9	−1.0	51	1	46	35	12	40	9	41	40	89	14.02	+.7	25	13,056	e.	65	sw.	24	3	2	26	8.6	0.0	0.0
dford	1,329	29	58	28.53	29.97	-----	38.2	-----	64	18	46	16	15	30	32	36	33	83	4.21	+1.1	17	3,959	n.	44	se.	26	2	7	22	8.3	1.6	0.0
tland, Oreg	153	68	106	29.75	29.92	−.15	40.2	−1.0	59	18	44	25	1	36	17	37	34	81	8.40	+1.7	24	3,793	se.	20	s.	7	2	2	27	8.8	1.0	0.0
eburg	510	75	99	29.38	29.94	−.17	42.3	+.5	62	18	49	27	1	36	32	40	37	83	6.60	+1.3	22	2,540	s.	20	sw.	27	1	5	25	8.8	1.5	0.0
iddle Pacific Coast Region							46.6	−1.8										79	7.73	+3.7										7.1		
eka	62	73	89	29.93	30.00	−.12	47.3	−.9	68	17	54	33	12	41	26	44	40	77	9.06	+2.8	20	5,553	se.	42	s.	17	4	8	19	7.3	0.0	0.0
Bluff	330	5	58	29.68	30.03	−.10	43.6	−2.5	62	4	51	28	14	37	29	41	37	81	7.95	+3.6	14	4,694	nw.	36	se.	26	7	5	19	7.2	9.0	0.0
ding	722	20	34	-----	-----	-----	43.4	-----	62	19	49	28	14	38	22	-----	-----	74	9.22	-----	16	5,446	nw.	-----	-----	-----	5	6	20	-----	7.2	0.0
amento	69	106	117	29.98	30.06	−.08	45.2	−1.0	59	4	51	30	12	39	26	43	41	84	6.84	+3.8	16	5,397	se.	31	se.	23	7	8	16	6.6	0.0	0.0
Francisco	155	208	243	29.87	30.04	−.08	49.4	−1.9	60	4	54	39	14	45	17	46	42	79	9.24	+5.3	20	4,140	se.	29	s.	23	4	9	18	7.4	T.	0.0
Jose	141	12	110	29.92	30.07	-----	47.4	−2.5	64	18	55	29	16	40	27	-----	-----	-----	5.57	+3.0	17	4,391	se.	29	se.	27	7	5	19	6.9	0.0	0.0
uth Pacific Coast Region							51.8	−1.1										71	4.29	+2.3										5.8		
no	327	89	98	29.73	30.10	−.03	46.7	+.5	65	3	54	30	15	39	25	43	40	78	3.36	+1.9	15	3,247	se.	22	nw.	28	5	10	16	7.1	0.0	-----
Angeles	338	159	191	29.71	30.08	+.01	55.0	−1.6	74	17	63	40	15	47	26	46	38	60	5.95	+3.3	8	3,525	ne.	24	e.	14	12	10	9	4.8	0.0	0.0
Diego	87	62	70	29.97	30.07	.00	53.8	−2.2	69	6	61	39	13	46	25	49	44	74	3.56	+1.7	9	3,409	nw.	30	s.	9	10	10	11	5.4	0.0	0.0
West Indies																																
Juan, P. R	82	9	54	29.92	30.01	-----	76.8	+.5	83	3	81	68	30	72	13	-----	-----	-----	4.57	−.9	25	10,637	e.	39	e.	14	6	23	2	4.9	0.0	0.0
Panama Canal																																
oa Heights	118	6	97	29.73	[1] 29.81	−.01	80.0	0.0	90	16	87	71	26	73	18	-----	-----	[1] 84	4.96	+.6	17	3,960	nw.	20	n.	28	0	20	11	7.2	0.0	0.0
tobal	36	6	97	29.80	[1] 29.82	−.01	81.6	+1.7	87	14	86	74	2	78	13	76	74	[1] 80	3.47	−7.4	15	7,806	n.	26	n.	11	6	14	11	6.3	0.0	0.0
Alaska																																
banks	455	11	44	-----	[2] 29.76	-----	−6.8	-----	32	11	2	−39	18	−15	35	-----	-----	84	1.73	-----	11	1,020	nw.	13	w.	11	11	3	17	-----	24.6	22.4
au	80	11	50	[2] 29.51	[2] 29.60	-----	32.8	-----	43	3	36	23	24	30	12	31	27	77	5.65	-----	17	4,607	s.	26	se.	18	4	8	19	7.8	20.5	4.7
awaiian Islands																																
olulu	38	86	100	[2] 29.97	[2] 30.01	-----	71.0	−1.4	79	2	76	60	7	66	15	65	62	75	2.08	−1.9	14	6,063	e.	43	e.	20	7	14	10	5.9	0.0	0.0

[1] Observations taken bihourly.

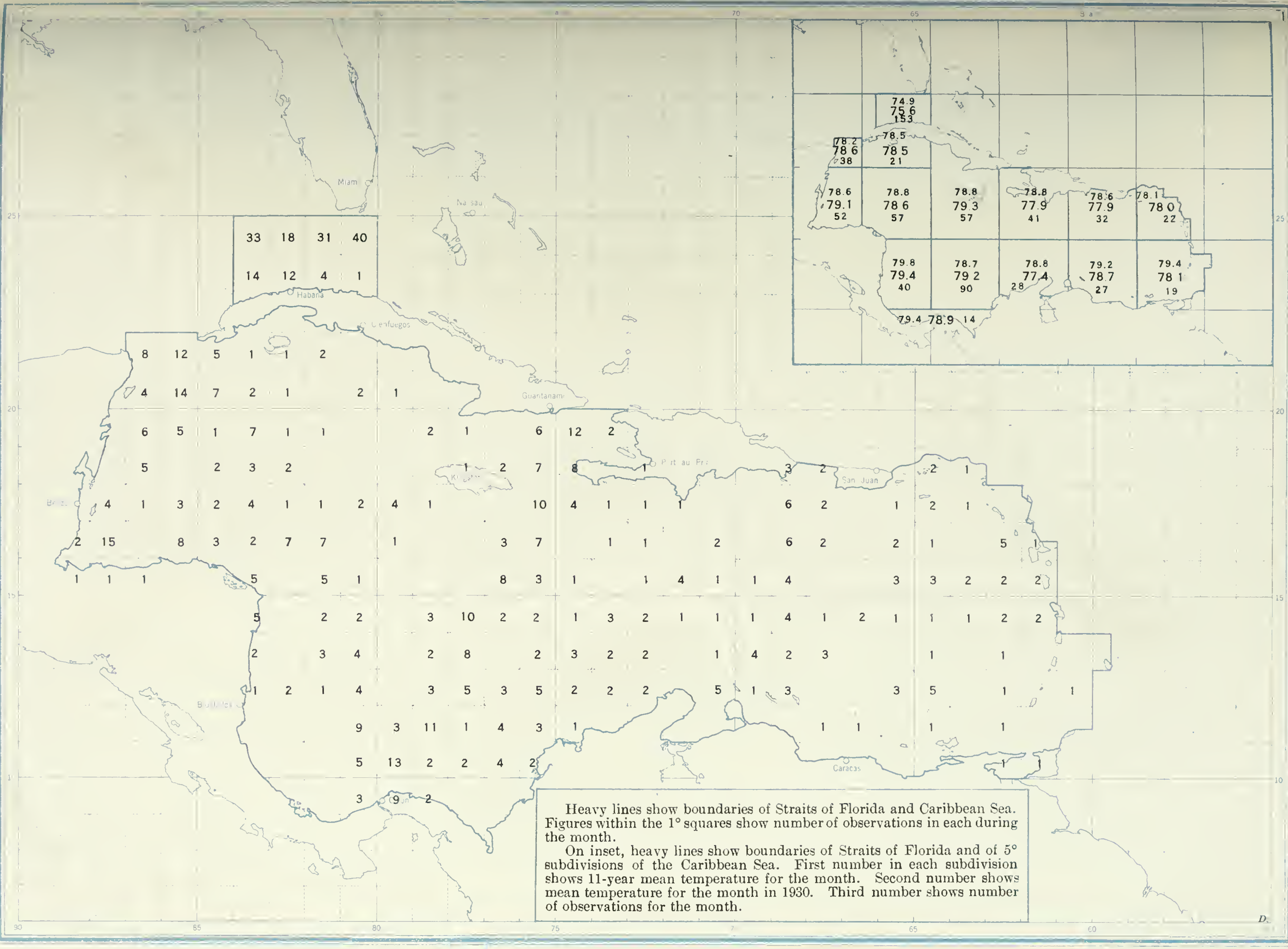
[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				29.6		35.3	23.9	45	6	6.75		20.2
Sydney, C. B. I	48	29.75	29.80	−0.09	29.4	+1.2	34.8	24.1	45	13	5.51	+0.88	18.5
Halifax, N. S	88	29.76	29.87	−.09	29.6	+2.0	36.0	23.3	51	8	5.57	+.45	5.0
Yarmouth, N. S	65	29.79	29.86	−.12	32.8	+2.1	38.9	26.8	51	15	4.51	−.26	3.0
Charlottetown, P. E. I	38	29.75	29.79	−.15	26.2	+1.9	31.6	20.9	45	4	5.23	+1.57	42.5
Chatham, N. B	28	29.79	29.83	−.11	20.1	+3.1	28.4	11.8	44	−11	3.00	−.22	24.[illegible]
Father Point, Que	20												
Quebec, Que	296	29.68	30.02	+.01	19.3	+4.1	25.4	13.2	41	−2	2.71	−.98	21.[illegible]
Doucet, Que	1,236				10.3		22.7	−2.0	37	−30	2.23		21.[illegible]
Montreal, Que	187	29.81	30.03	.00	24.7	+6.4	31.8	17.5	46	−1	3.36	−.29	20.[illegible]
Ottawa, Ont	236	29.80	30.09	+.07	23.9	+6.9	31.5	16.3	48	−2	2.51	−.40	12.[illegible]
Kingston, Ont	285	29.76	30.09	+.05	30.1	+6.4	37.3	22.9	48	4	2.53	−.71	3.[illegible]
Toronto, Ont	379	29.67	30.10	+.05	33.3	+6.3	38.8	27.8	51	10	3.00	+.09	6.[illegible]
Cochrane, Ont	930				14.7		23.5	5.9	38	−18	1.47		9.[illegible]
White River, Ont	1,244	28.68	30.04	+.07	16.5	+6.8	27.0	6.0	40	−20	1.06	−.65	10.[illegible]
London, Ont	808				32.9		38.8	27.0	53	17	2.10		3.[illegible]
Southampton, Ont	656	29.35	30.08	+.07	31.3	+4.6	37.1	25.5	46	9	2.97	−1.01	12.[illegible]
Parry Sound, Ont	688	29.37	20.08	+.08	26.0	+4.8	32.9	19.1	44	−2	2.90	−1.58	15.[illegible]
Port Arthur, Ont	644	29.33	30.06	+.07	25.5	+12.3	32.0	19.1	43	0	.96	+.09	4.[illegible]
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.12	30.01	−.01	16.5	+10.8	24.7	8.4	39	−19	.05	−.57	.[illegible]
Le Pas, Man	860				10.9		20.8	1.0	37	−23	.54		5.[illegible]
Qu'Appelle, Sask	2,115	27.60	29.92	−.08	19.0	+11.6	26.5	11.5	40	−16	.48	−.04	.[illegible]
Moose Jaw, Sask	1,759				22.3		31.8	12.8	45	−9	.55		2.[illegible]
Swift Current, Sask	2,392	27.26	29.88	−.11	21.7	+5.7	29.2	14.2	44	−8	1.30	+.52	10.[illegible]
Medicine Hat, Alb	2,365												
Calgary, Alb	3,428												
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.32	29.97	−.04	13.5	+10.7	21.9	5.1	40	−29	1.34	+.60	13.[illegible]
Battleford, Sask	1,592	28.13	29.95	−.04	12.7	+7.3	22.7	2.8	43	−19	.85	+.53	8.[illegible]
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.57	29.83	−.14	41.8	+0.6	44.9	38.7	53	32	2.62	−5.36	.[illegible]
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151	30.04	30.20	+.08	65.9	+1.2	72.4	59.3	77	50	2.11	−2.38	

○

Distribution of Greenwich Mean Noon Ba[illegible]ks Observations of Sea-Surface Temperatures, January, 1930



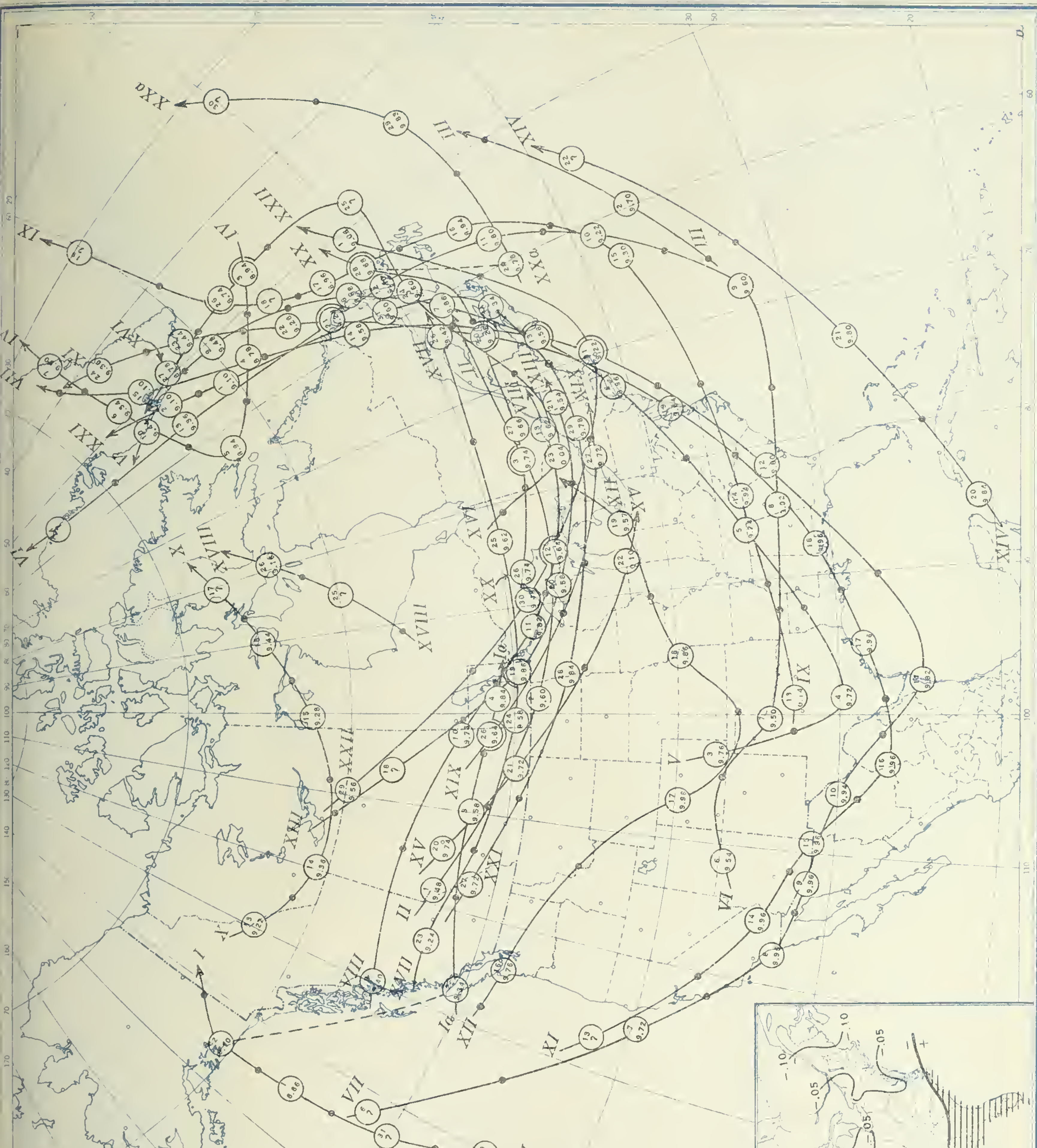
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, January, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, January, 1931

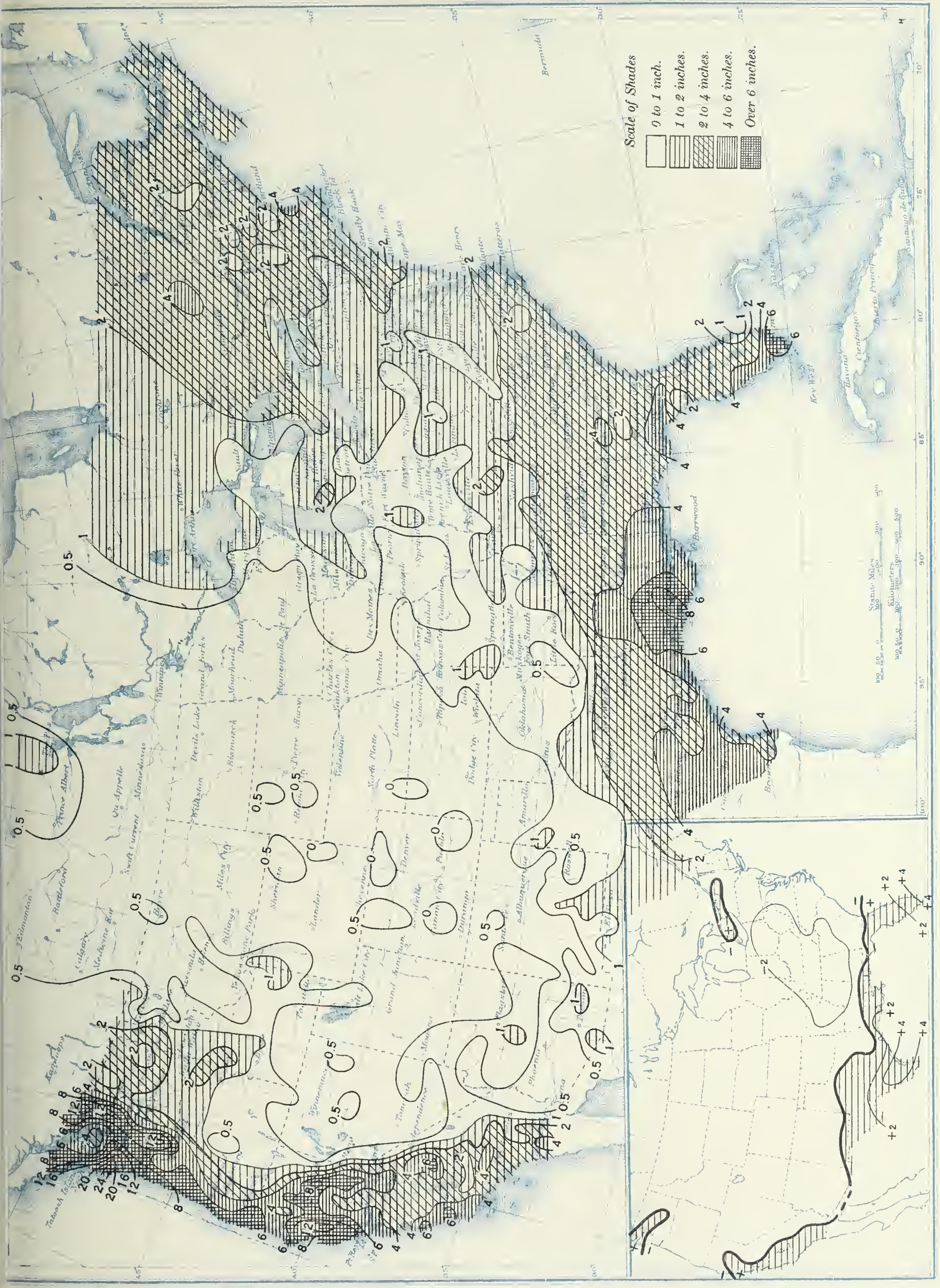
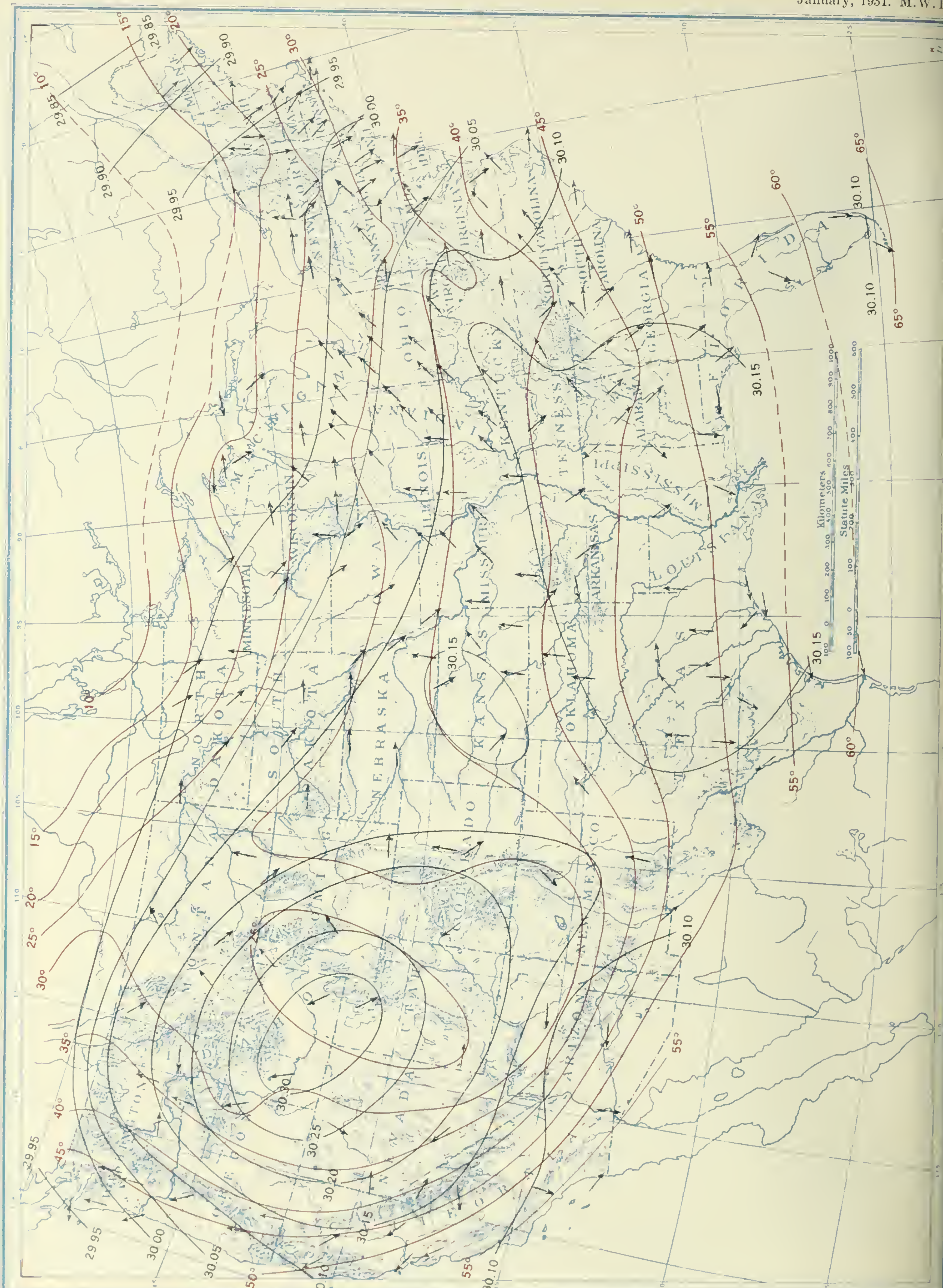
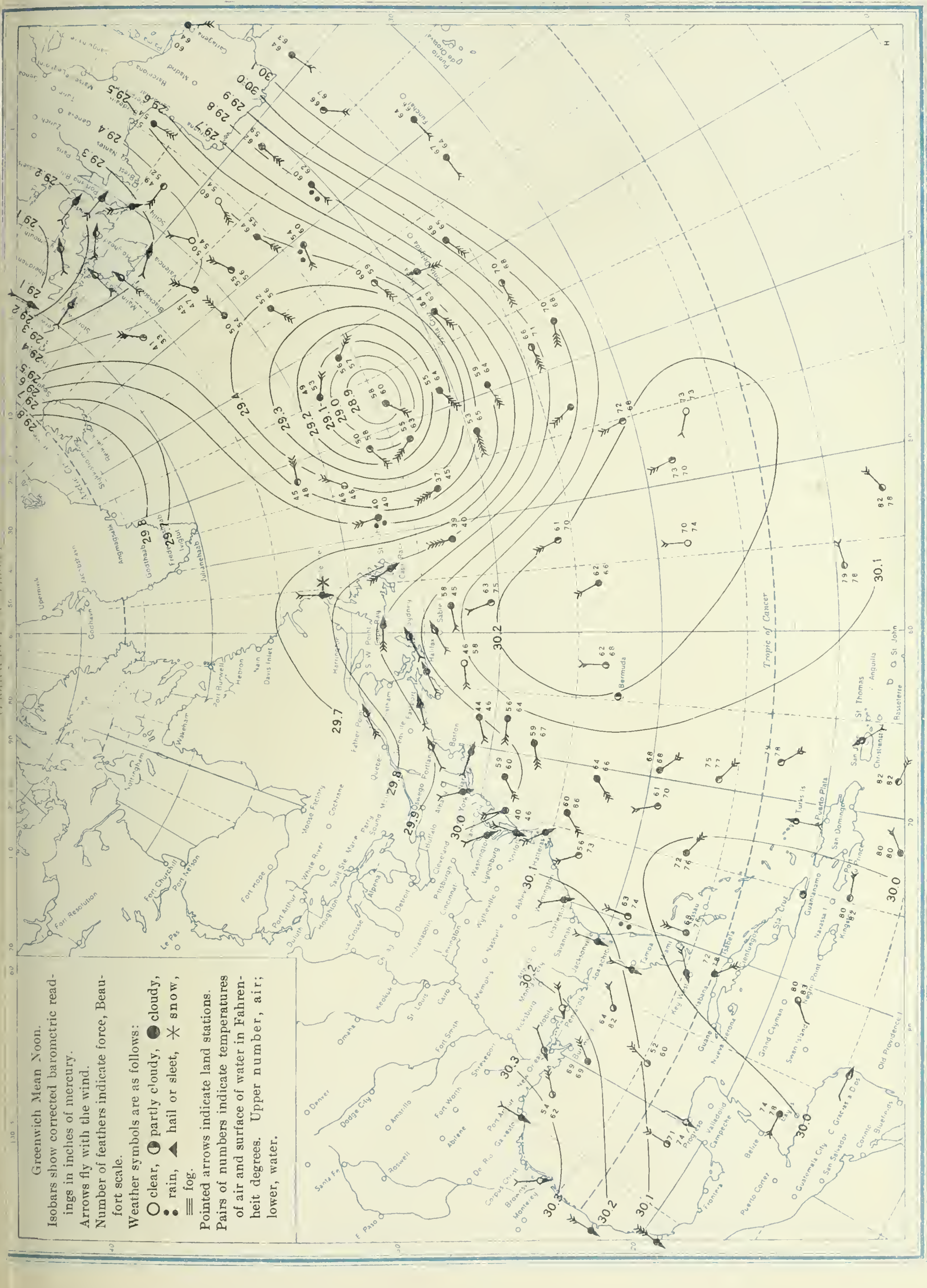

Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, January, 1931





Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows: ○ clear, ◐ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

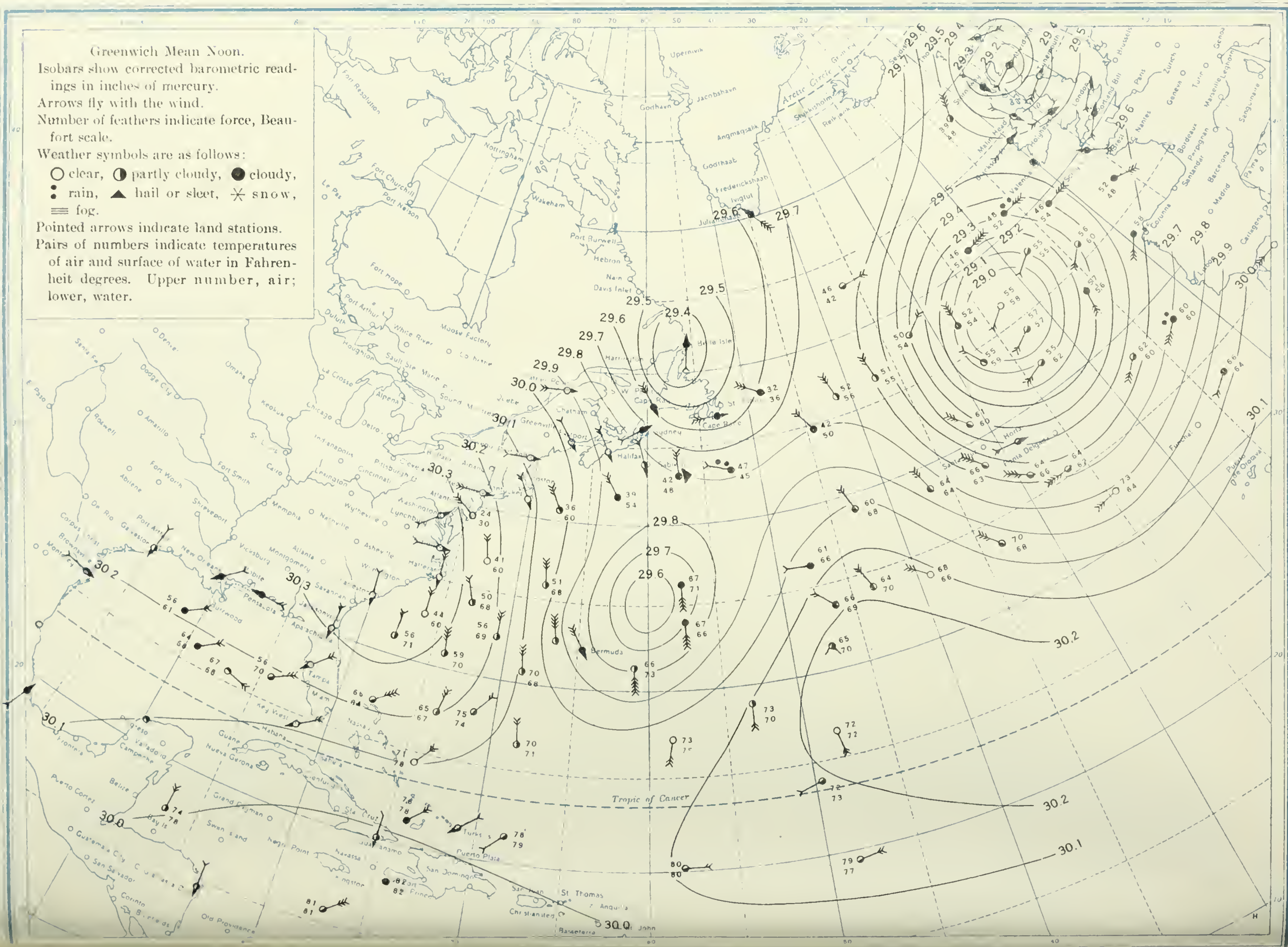
Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

(Plotted by F. A. Young)

Chart IX. Weather Map of North Atlantic Ocean, January 2, 1931

(Plotted by F. A. Young)



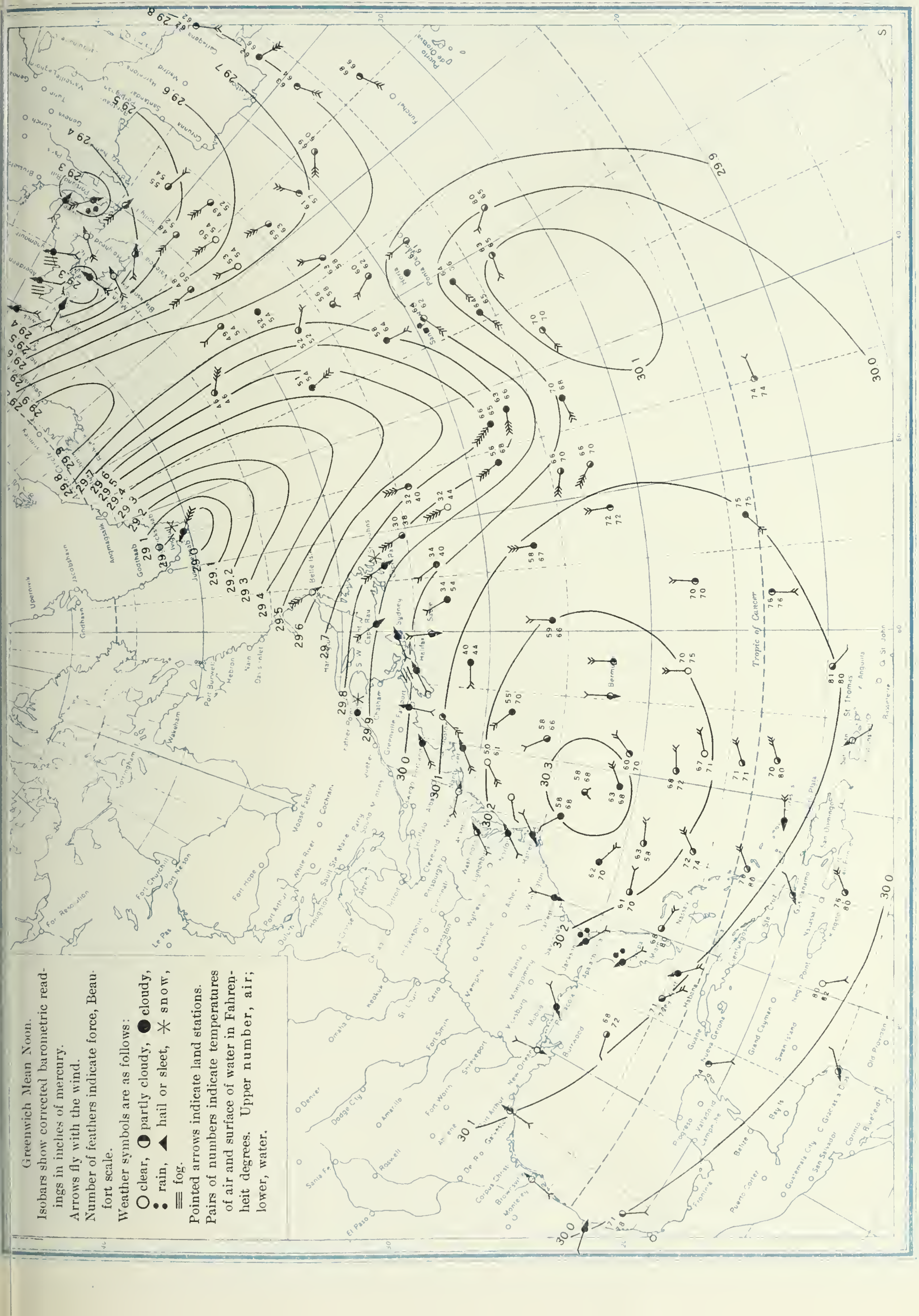
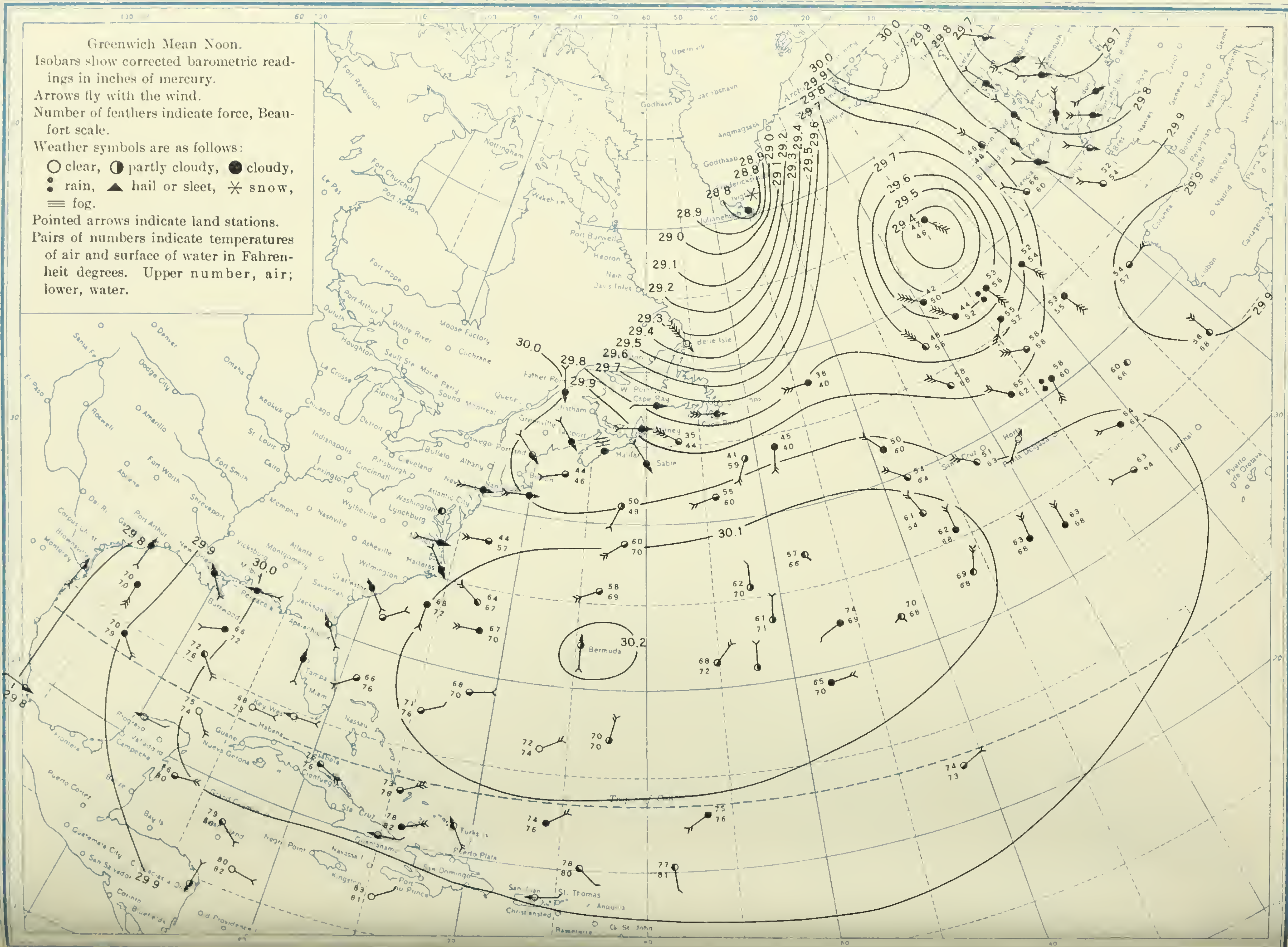
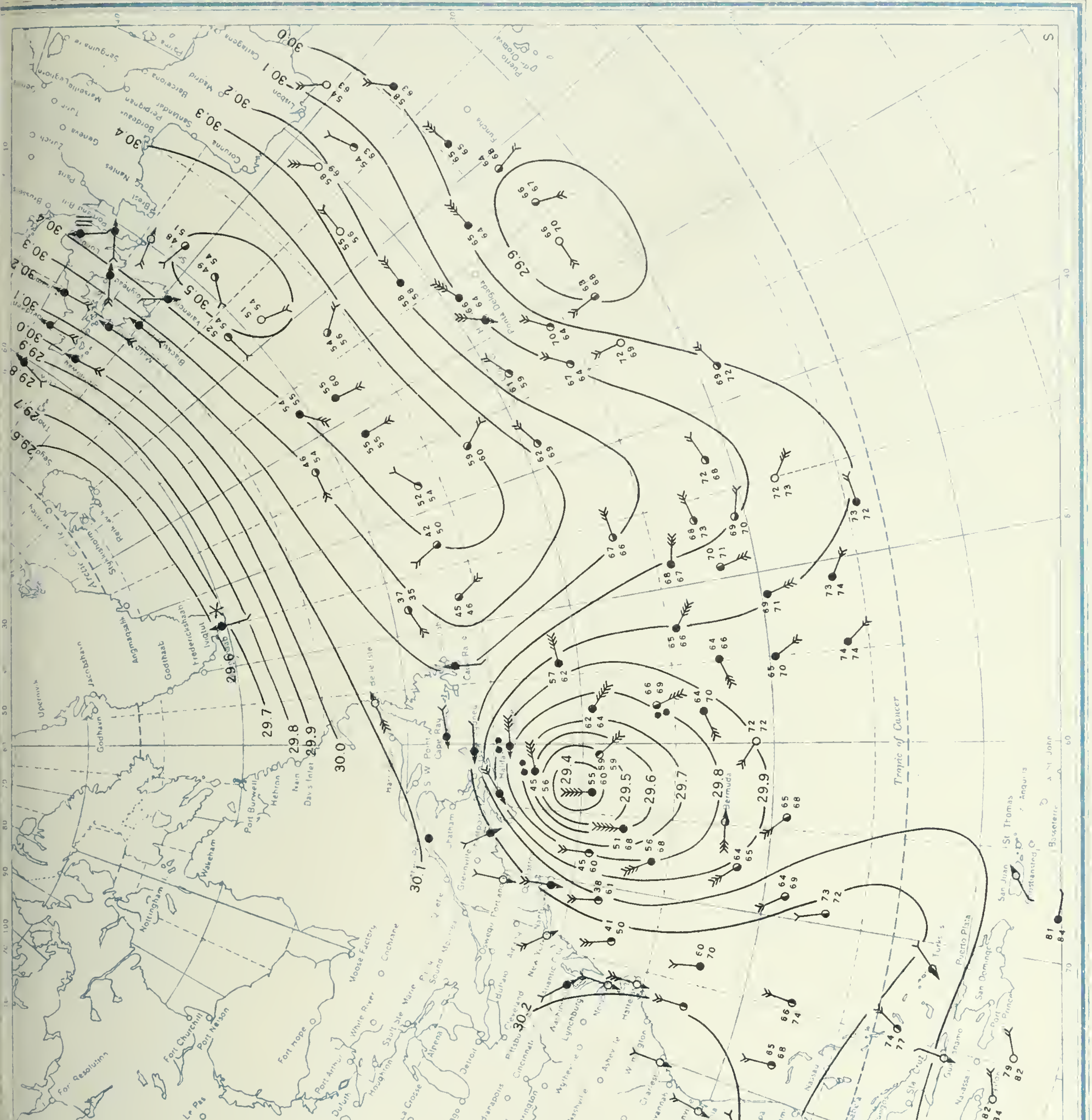

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◑ partly cloudy, ● cloudy, ⁏ rain, ▲ hail or sleet, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer

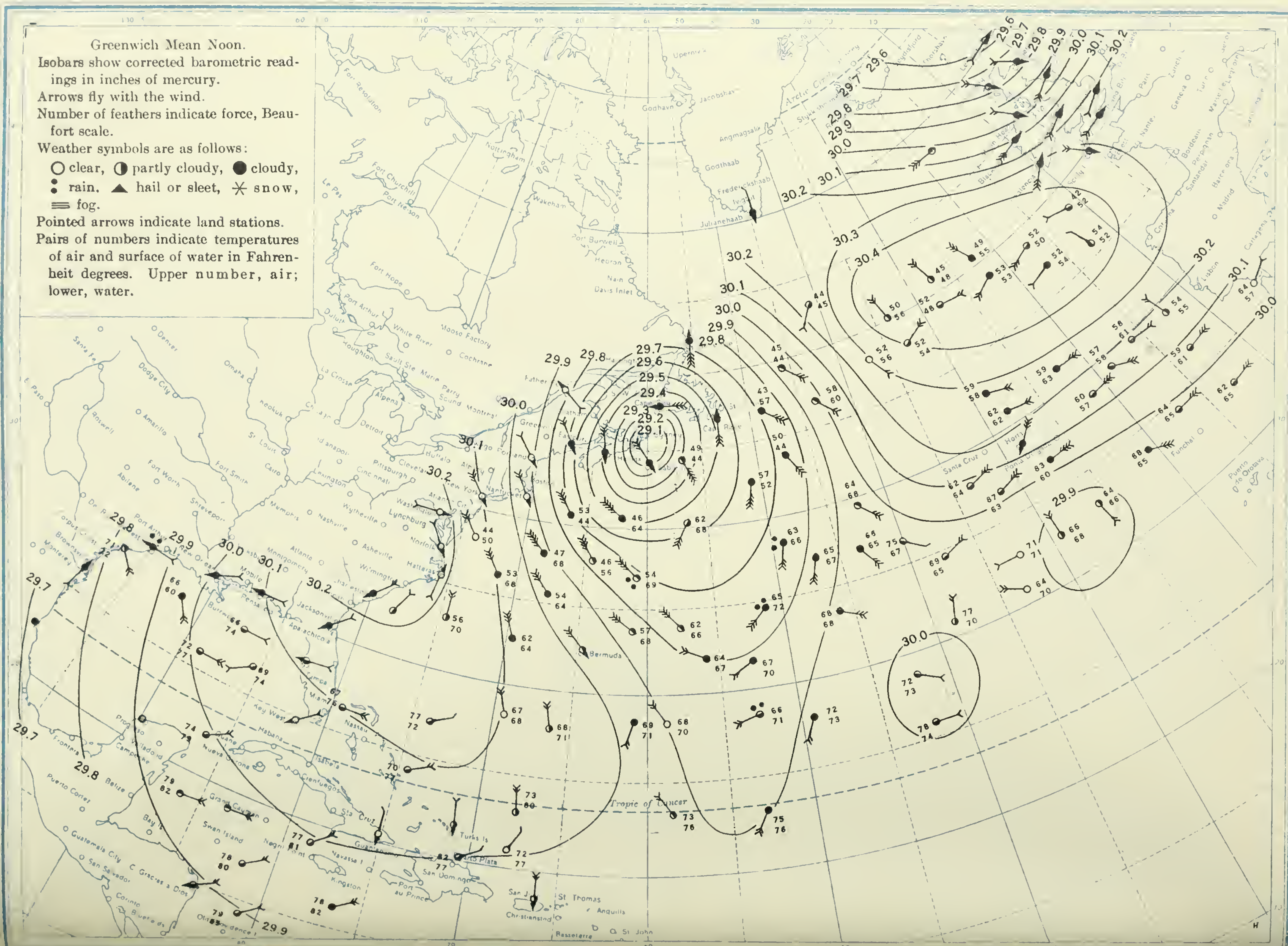
Chart XI. Weather Map of North Atlantic Ocean, January 4, 1931
(Plotted by F. A. Young)





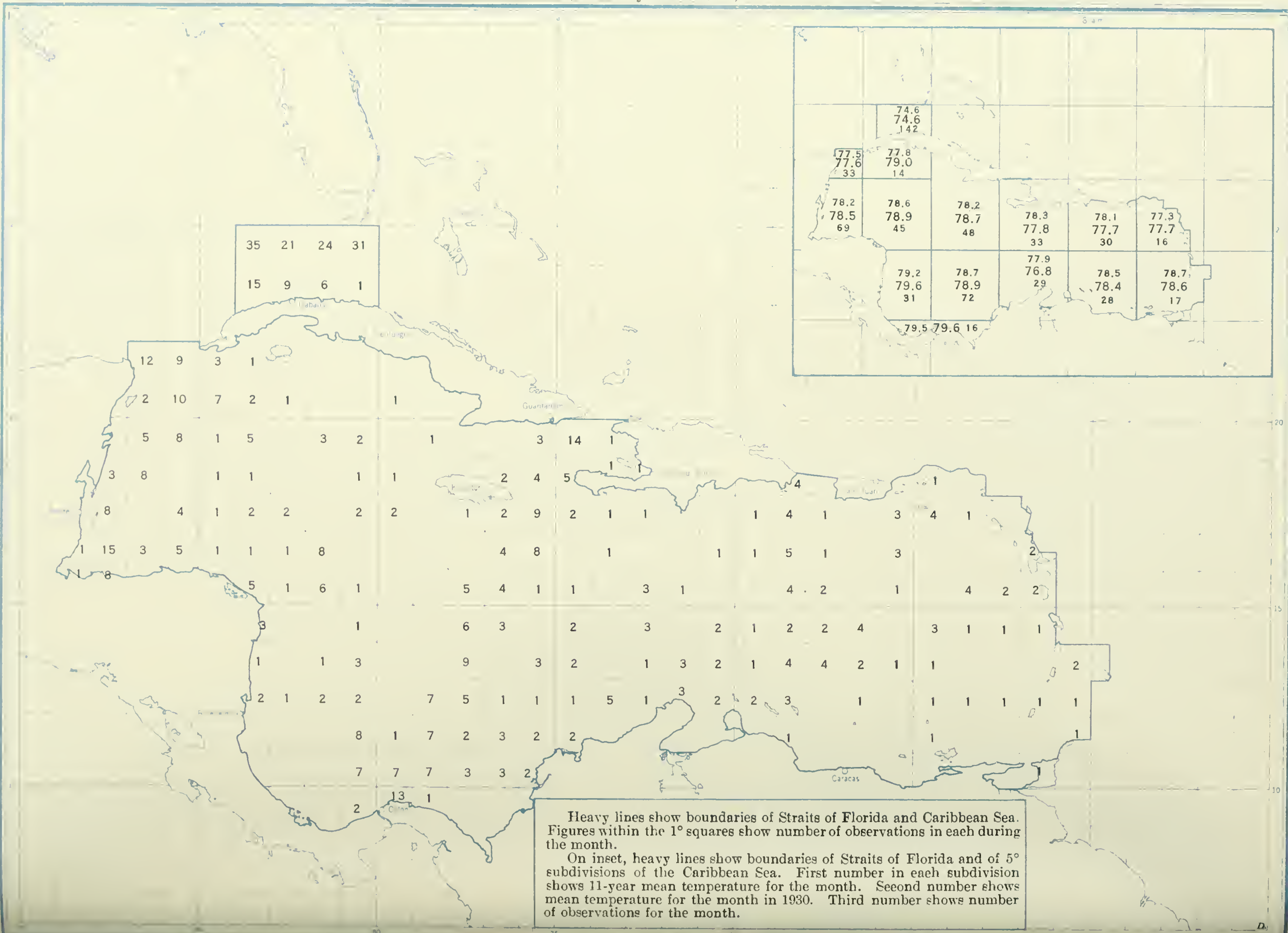
(Plotted by F. A. Young)

Chart XIII. Weather Map of North Atlantic Ocean, January 11, 1931
(Plotted by F. A. Young)



Distribution of Greenwich Mean Noon Bucket Observations of Sea Surface Temperatures, February, 1930

(Plotted by Giles Slocum)



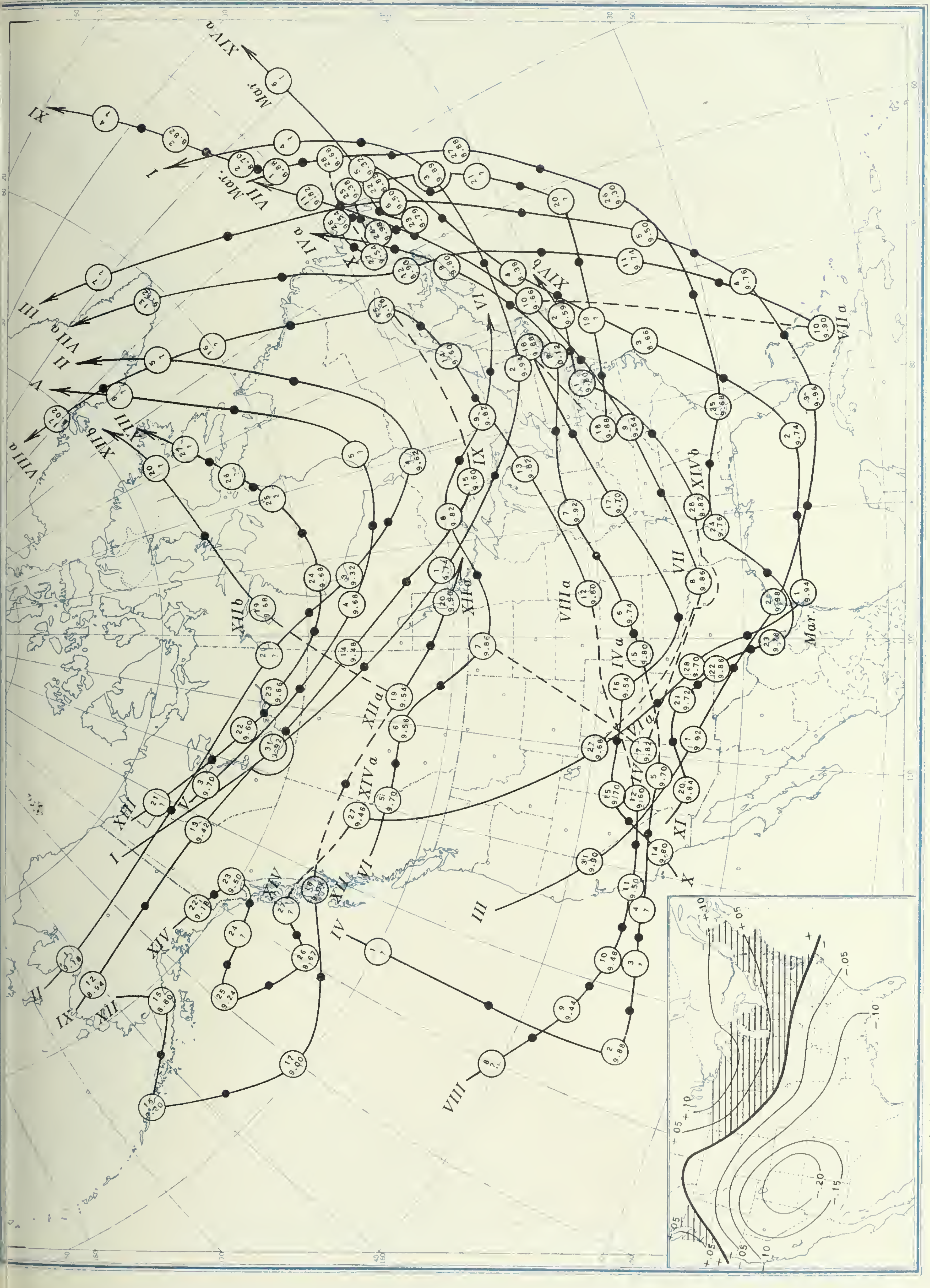
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, February, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Arthur J. Haidle)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, February, 1931

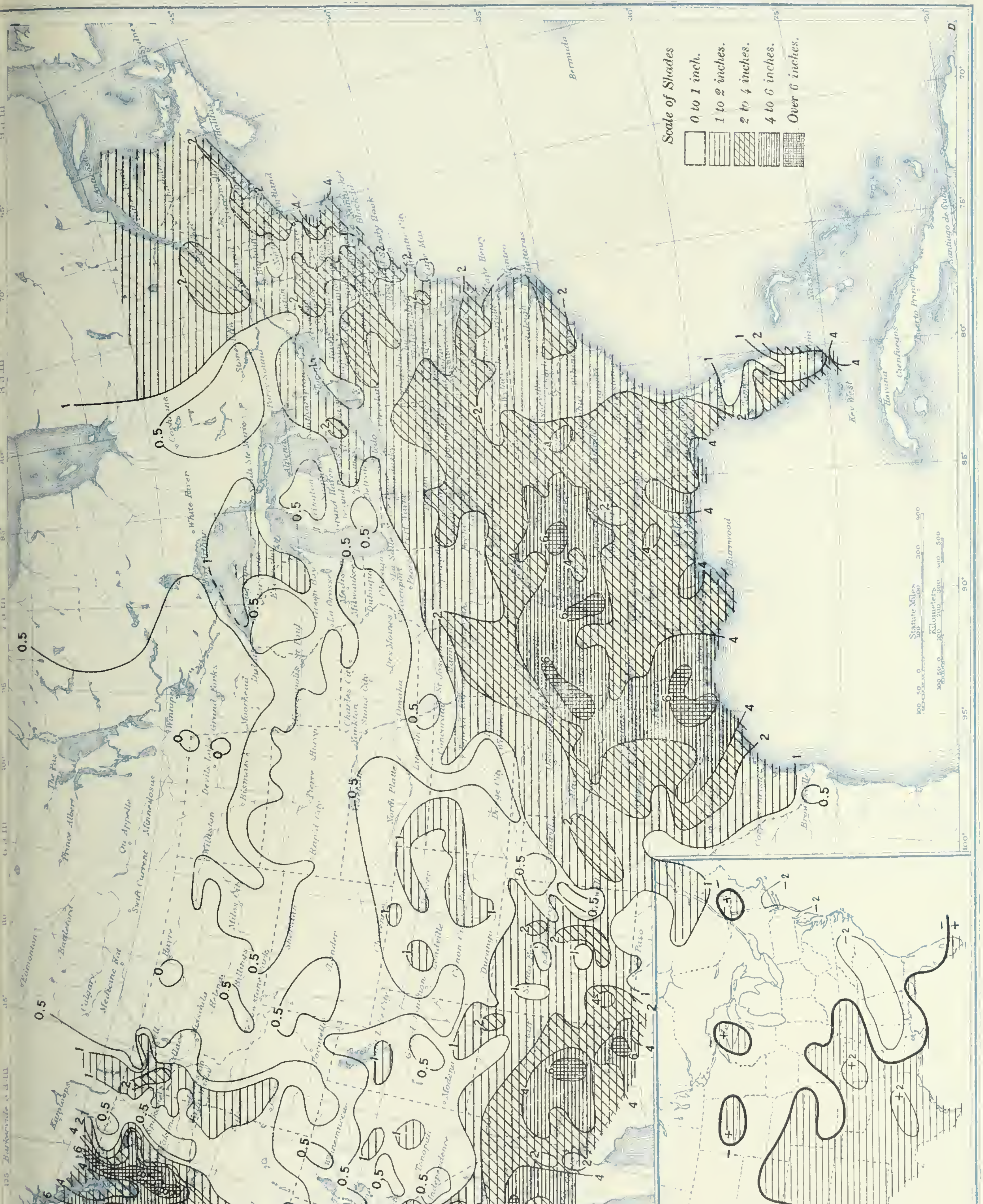
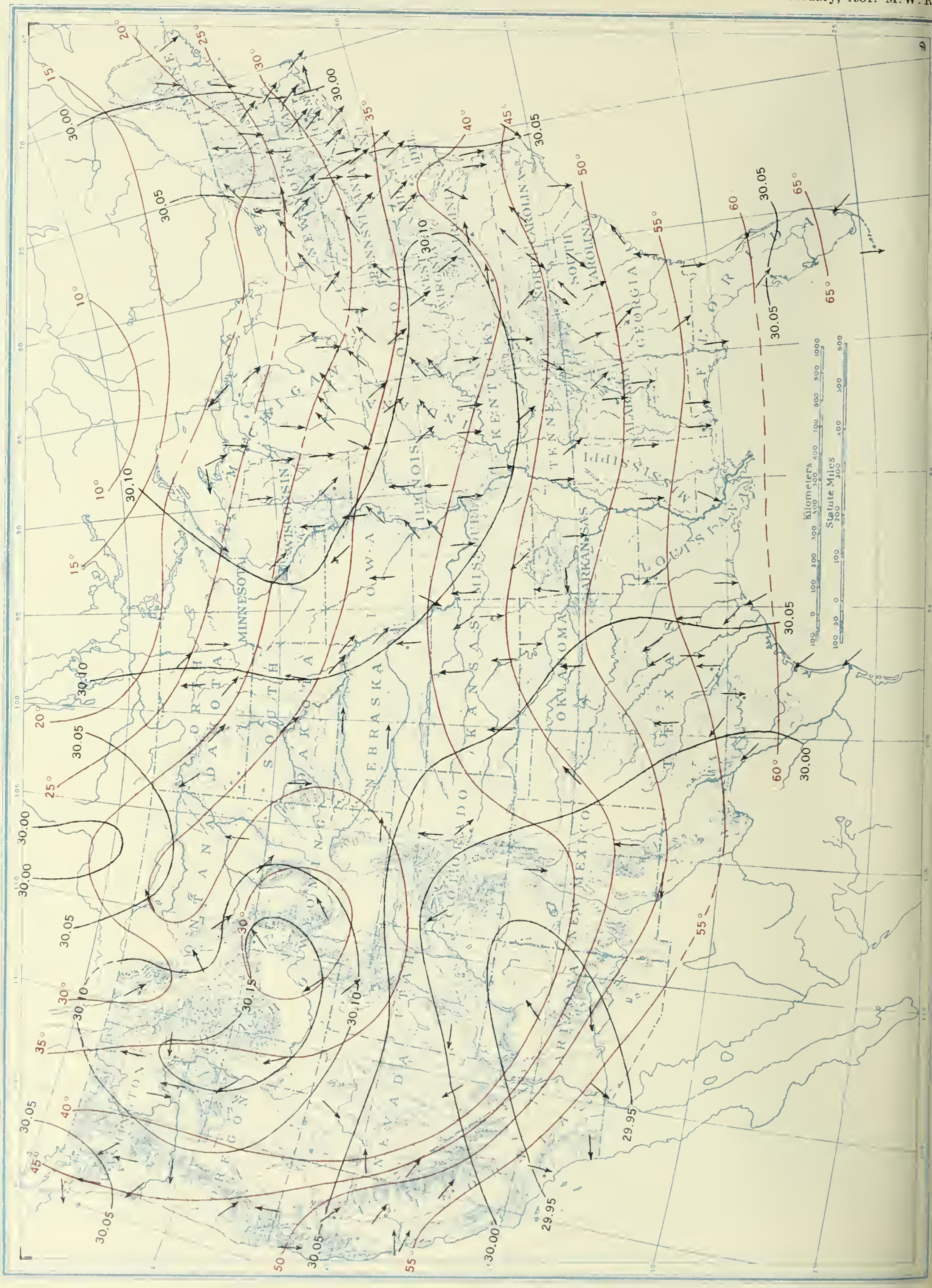
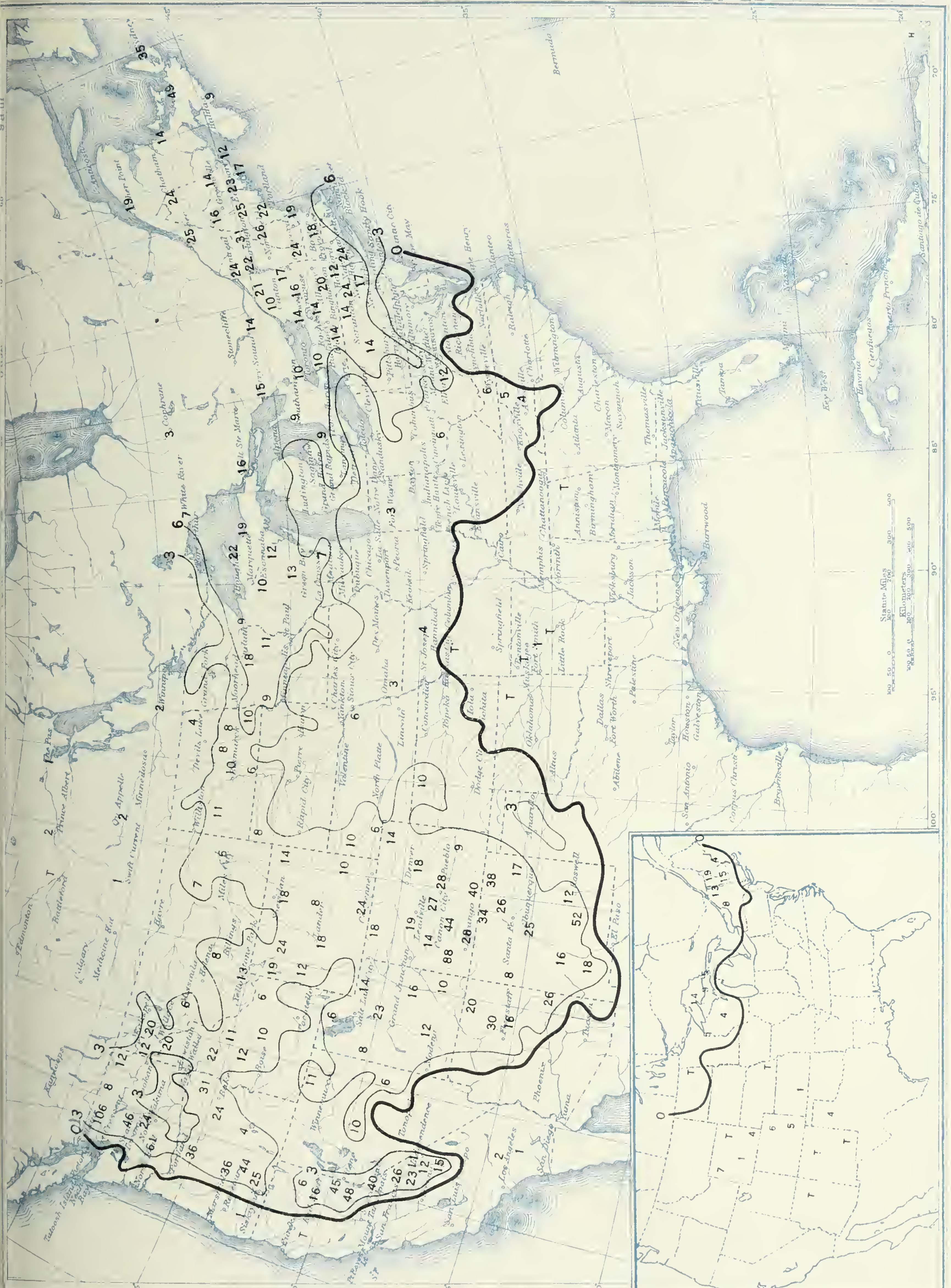

Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, February, 1931





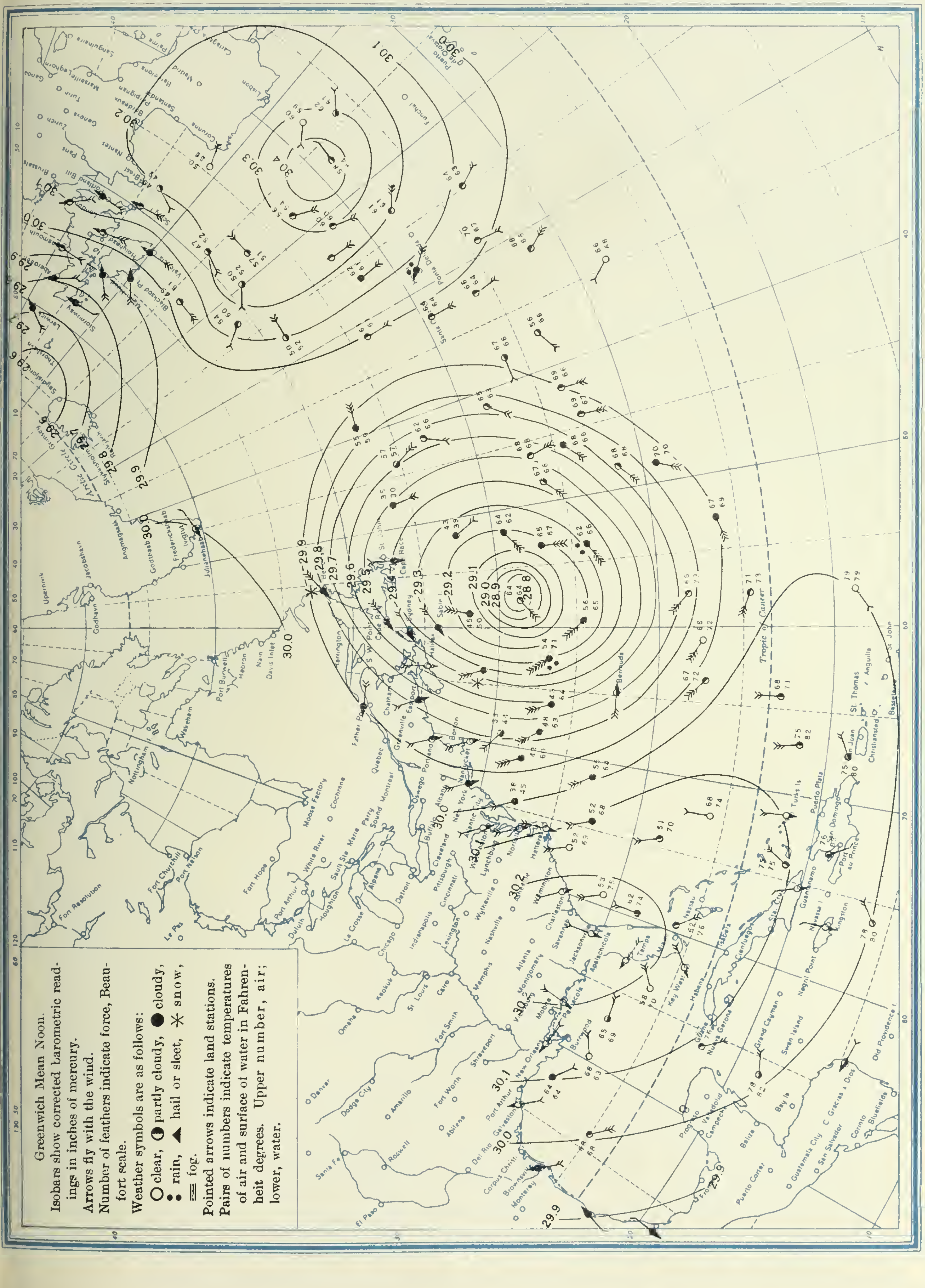
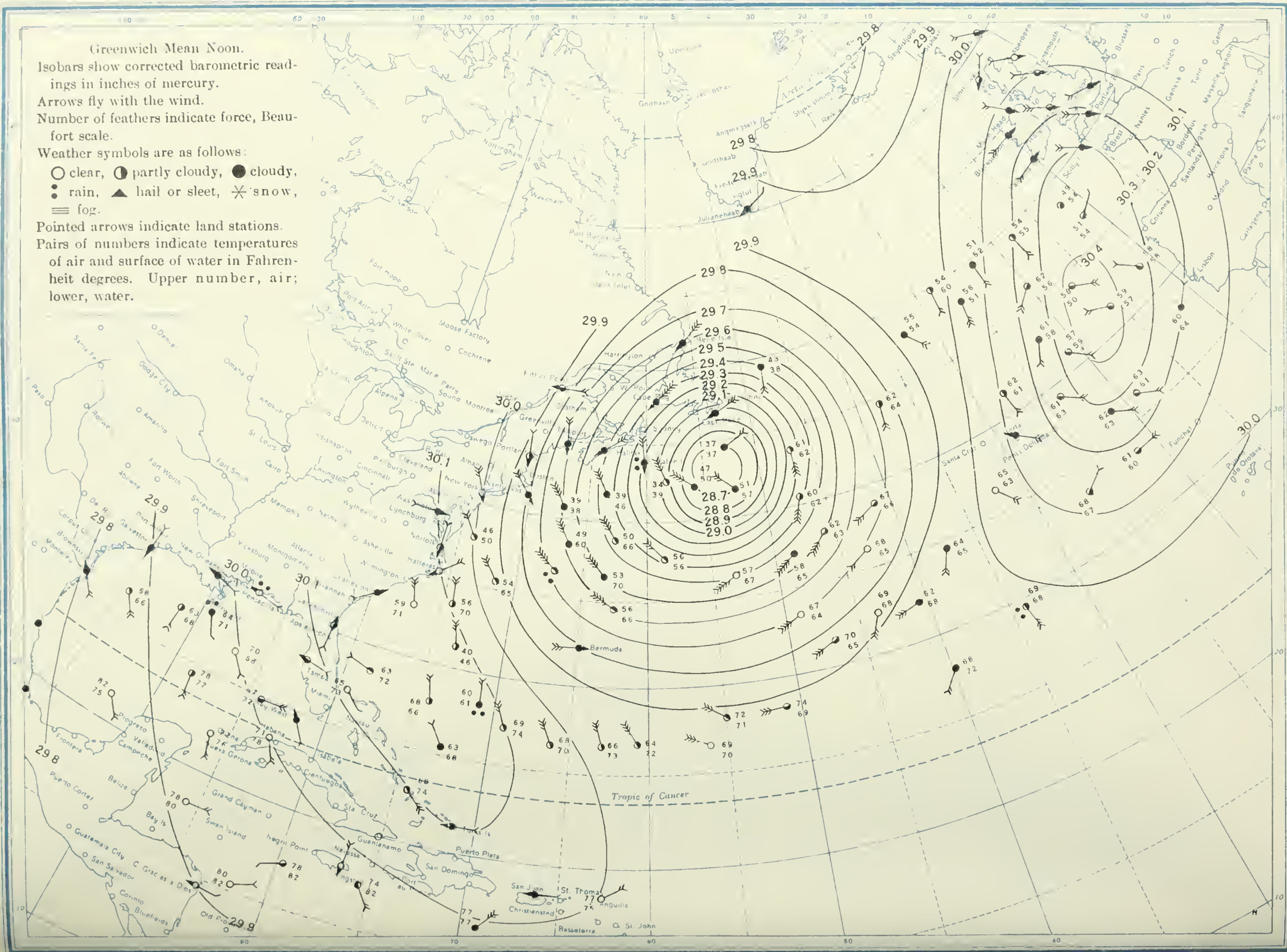

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart IX. Weather Map of North Atlantic Ocean, February 23, 1931

(Plotted by F. A. Young)



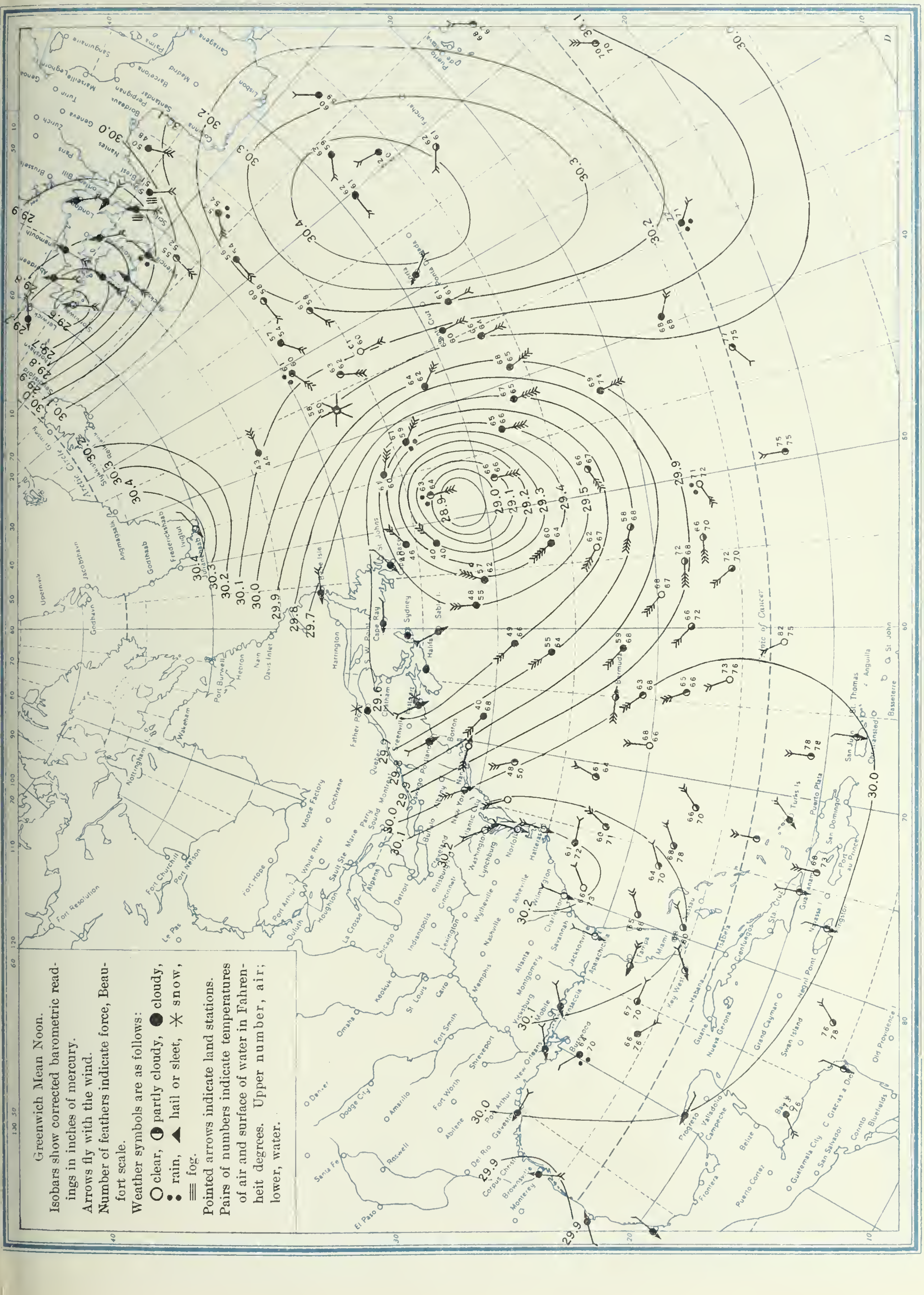
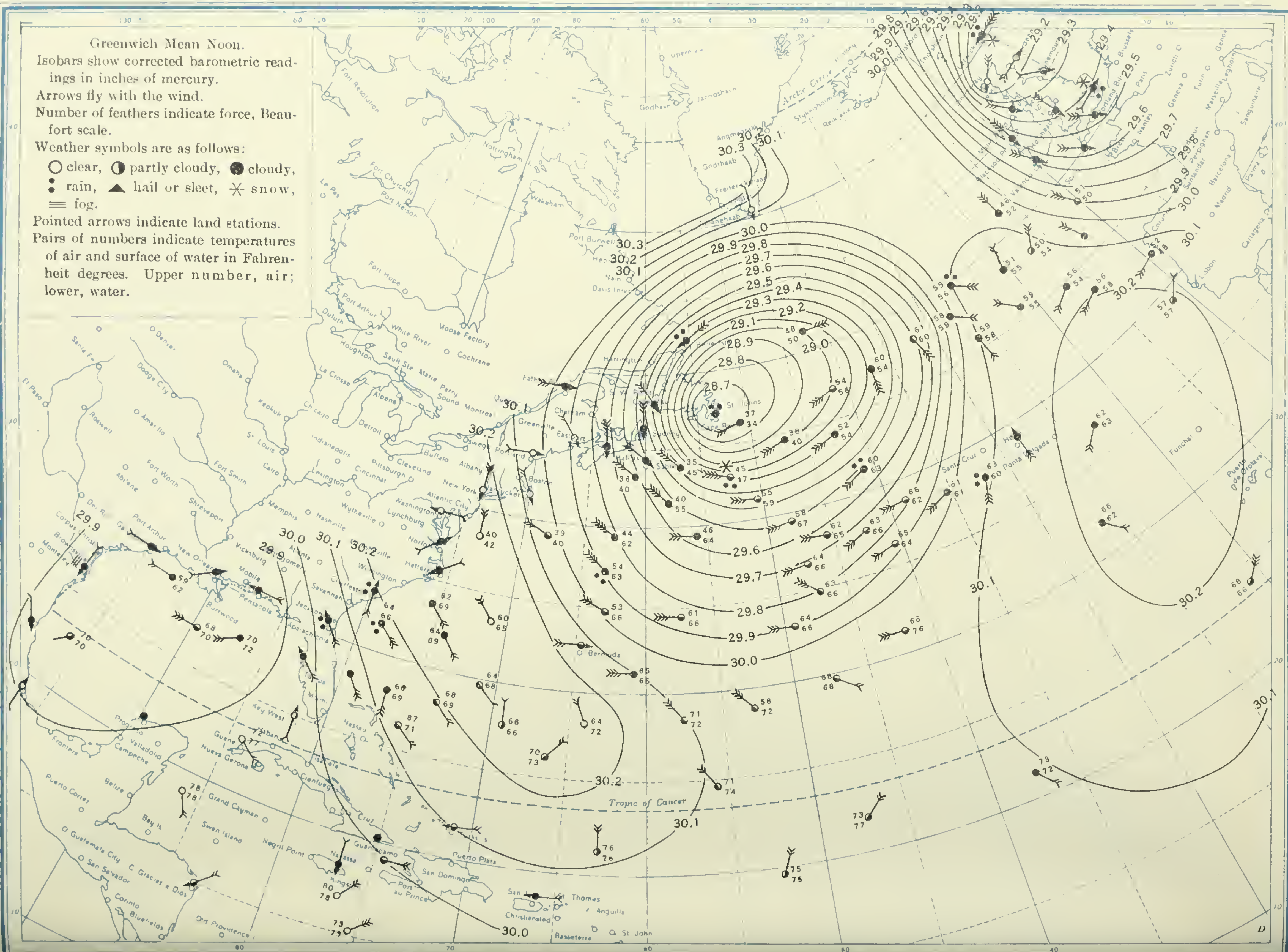
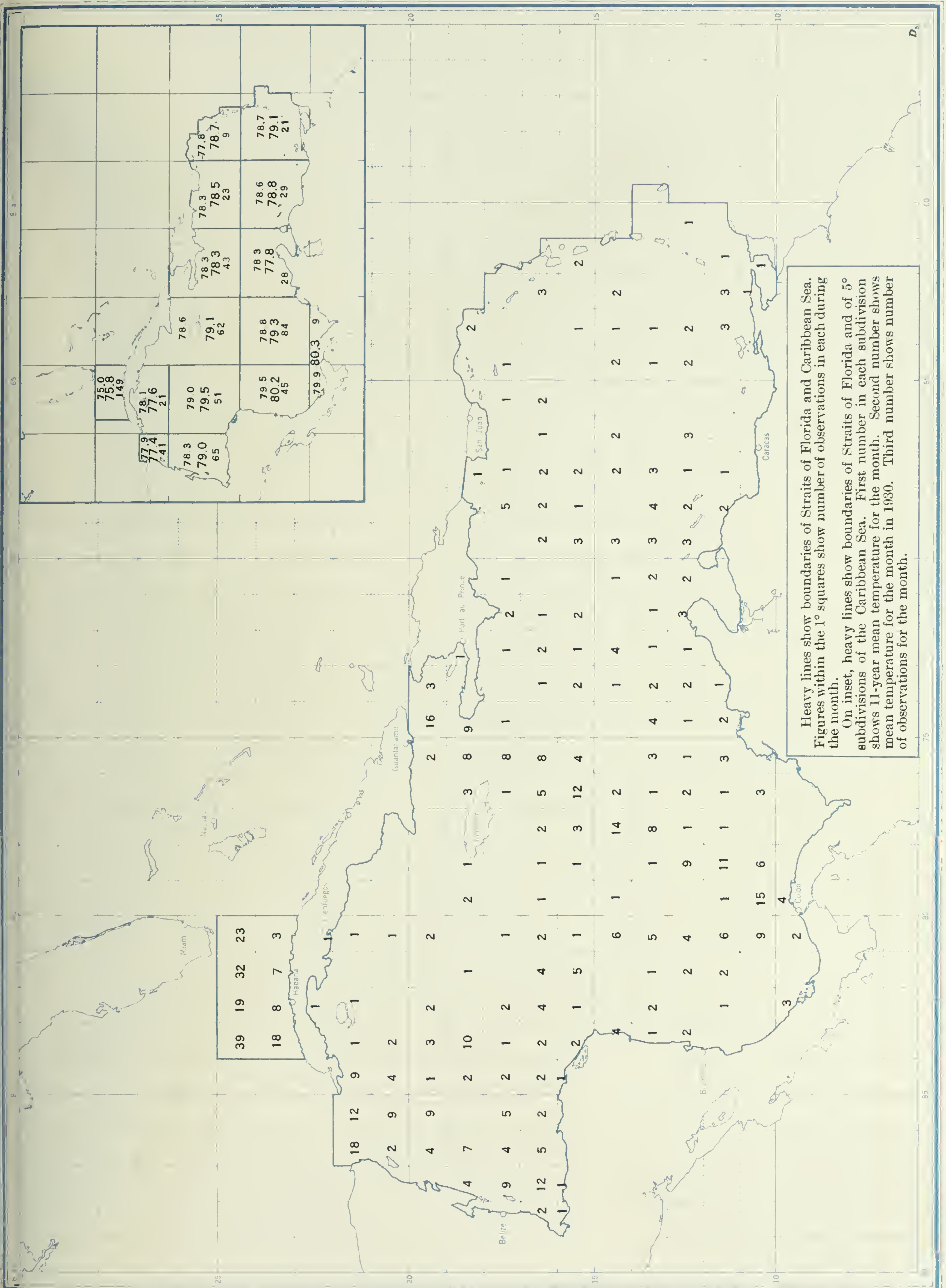

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◐ partly cloudy, ● cloudy, ⁚ rain, ▲ hail or sleet, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
D

Chart XI. Weather Map of North Atlantic Ocean, February 28, 1931
(Plotted by F. A. Young)



Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◐ partly cloudy, ● cloudy, ⁚ rain, ▲ hail or sleet, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

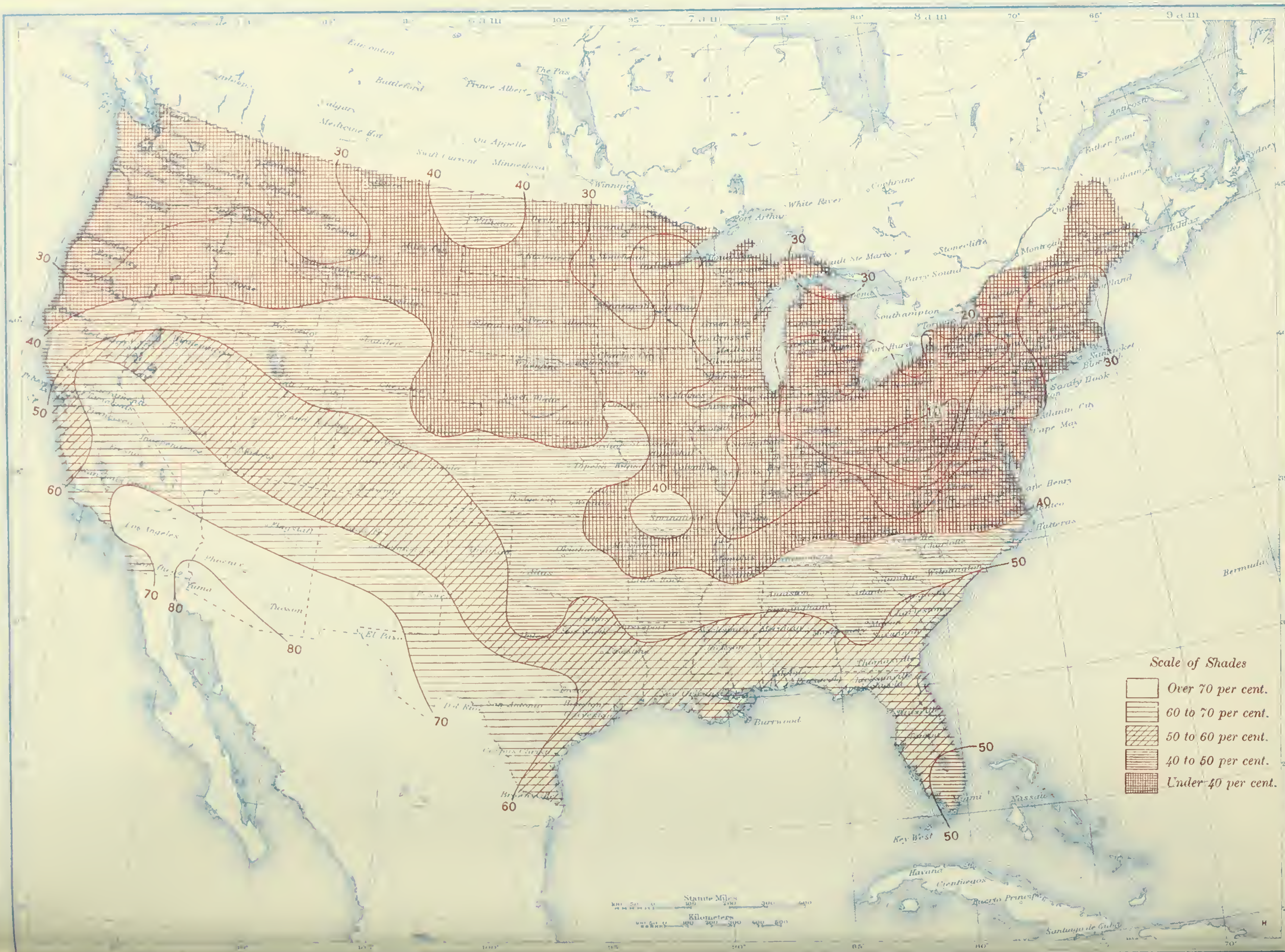

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, March, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)

Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time)

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, March, 1931




D.
Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.
Statute Miles
Kilometers

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, March, 1931

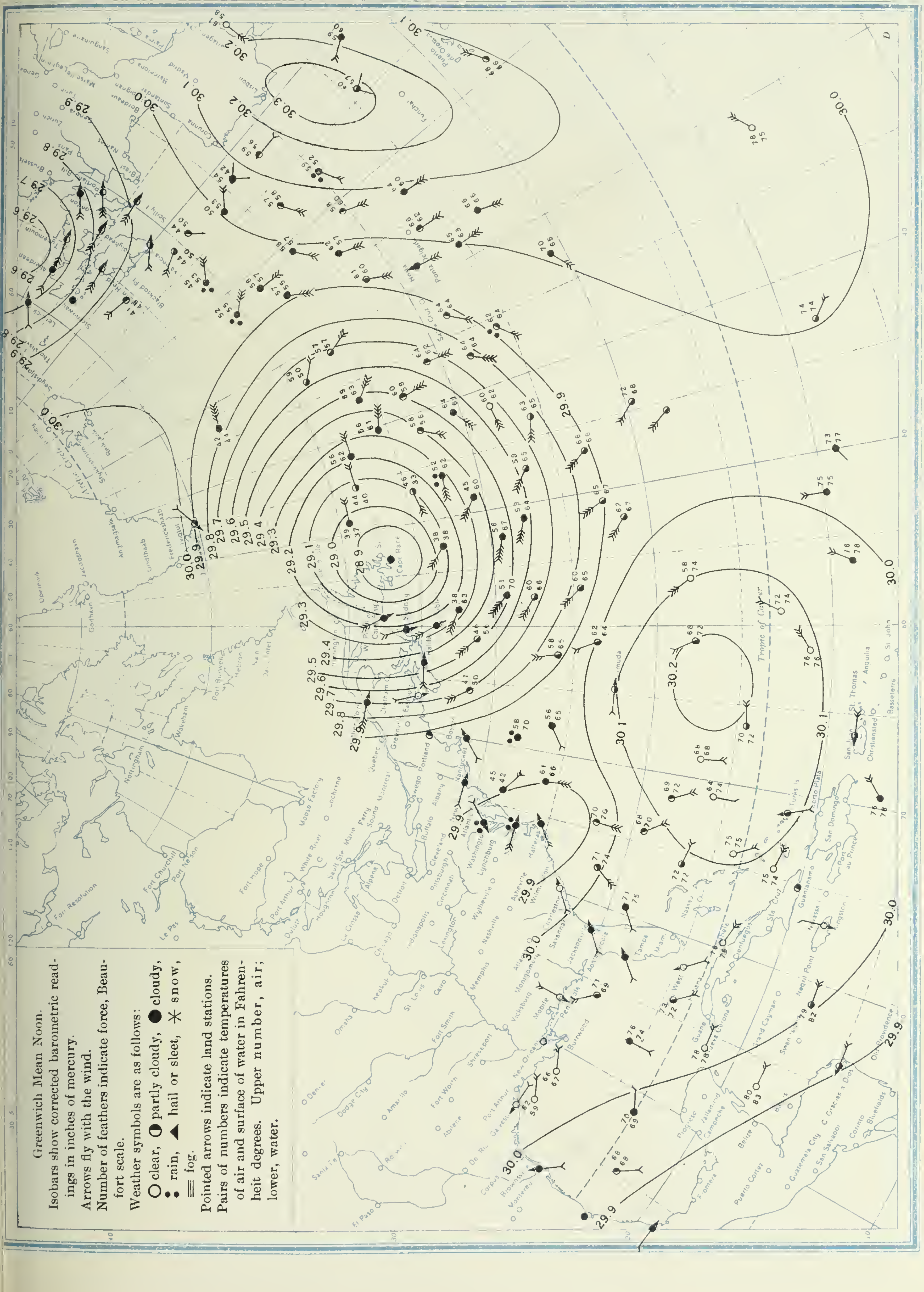
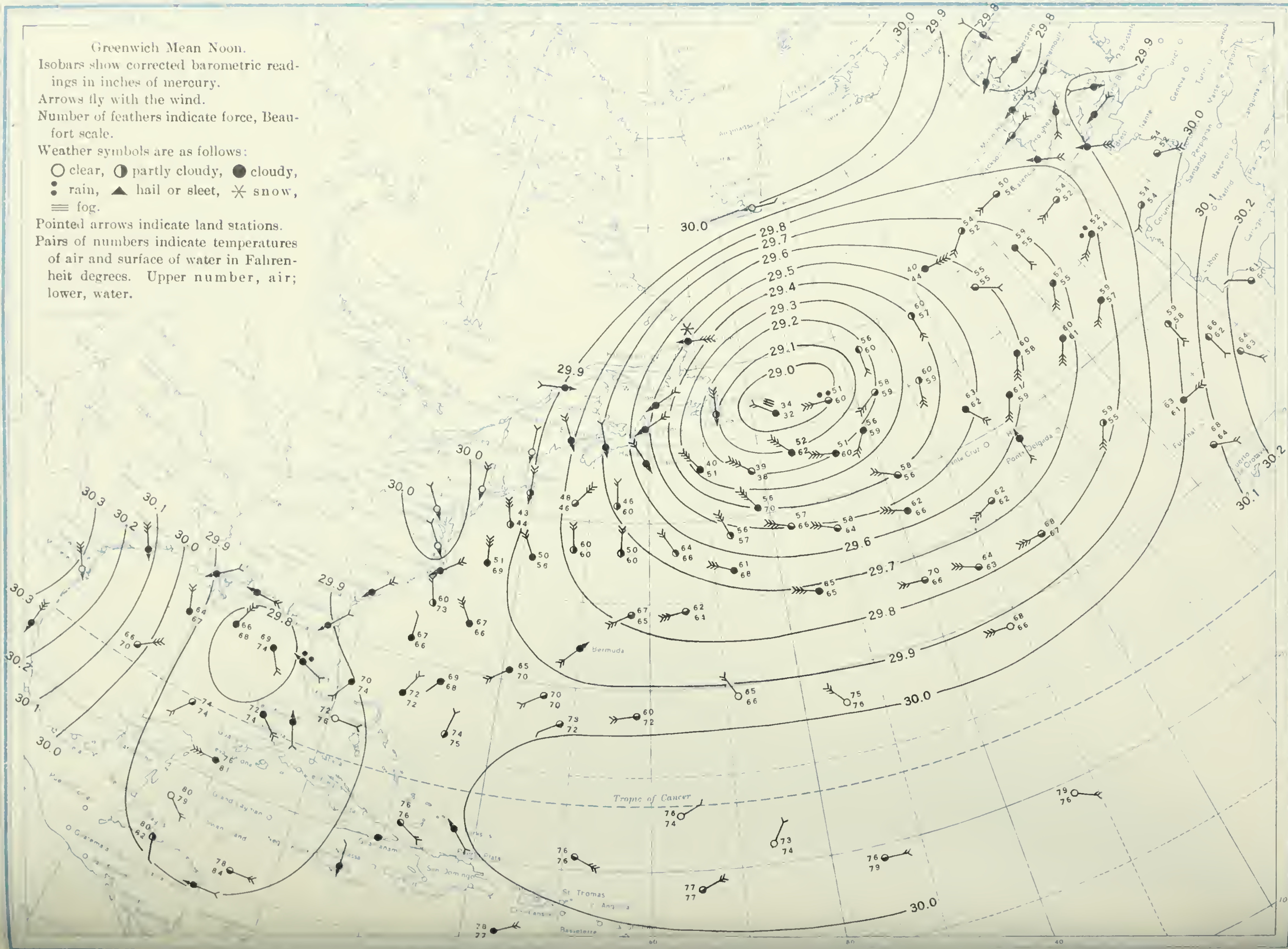

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◐ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✱ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart IX. Weather Map of North Atlantic Ocean, March 2, 1931

(Plotted by F. A. Young)



Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows: ○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

(Plotted by F. A. Young)

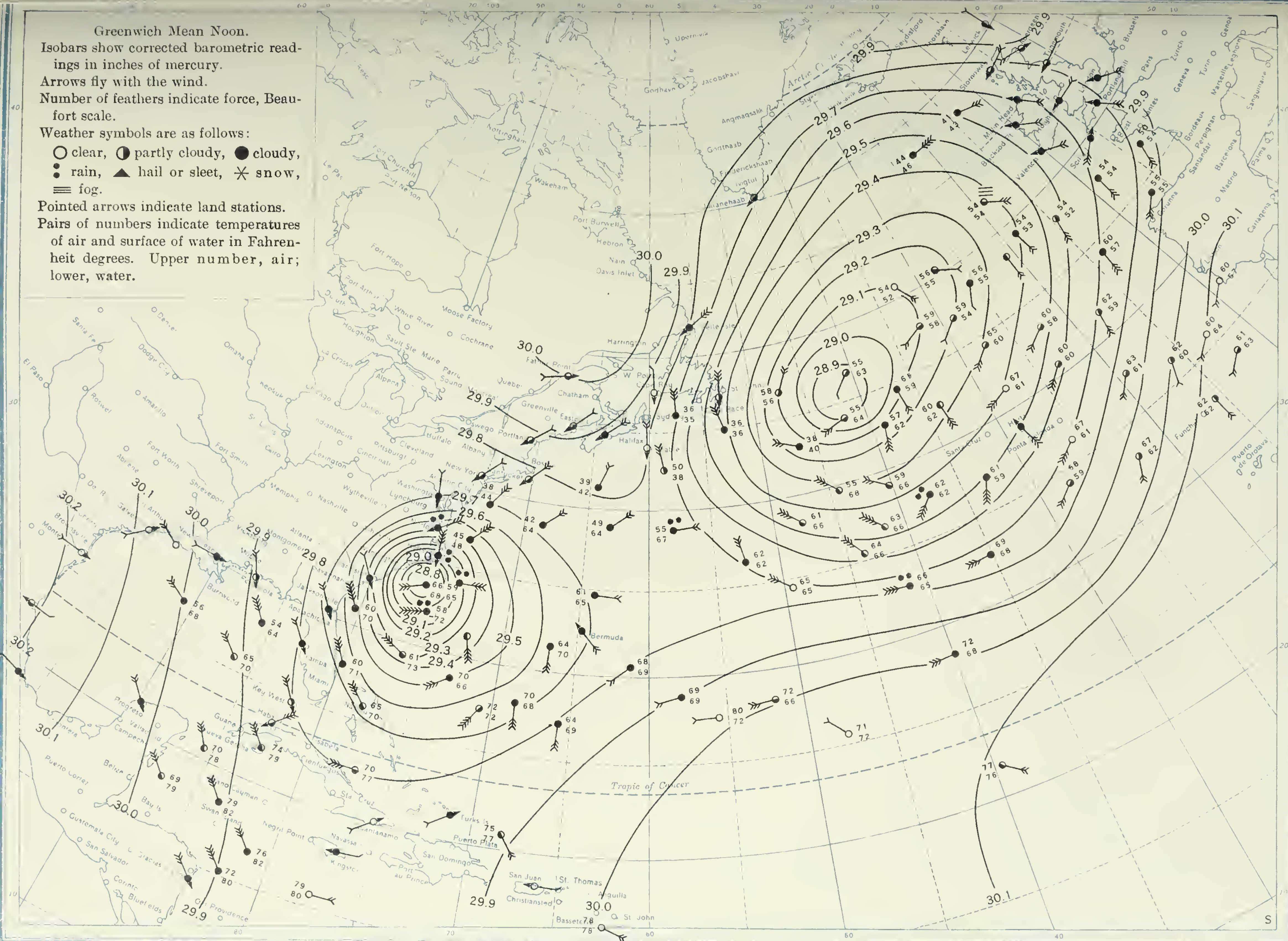
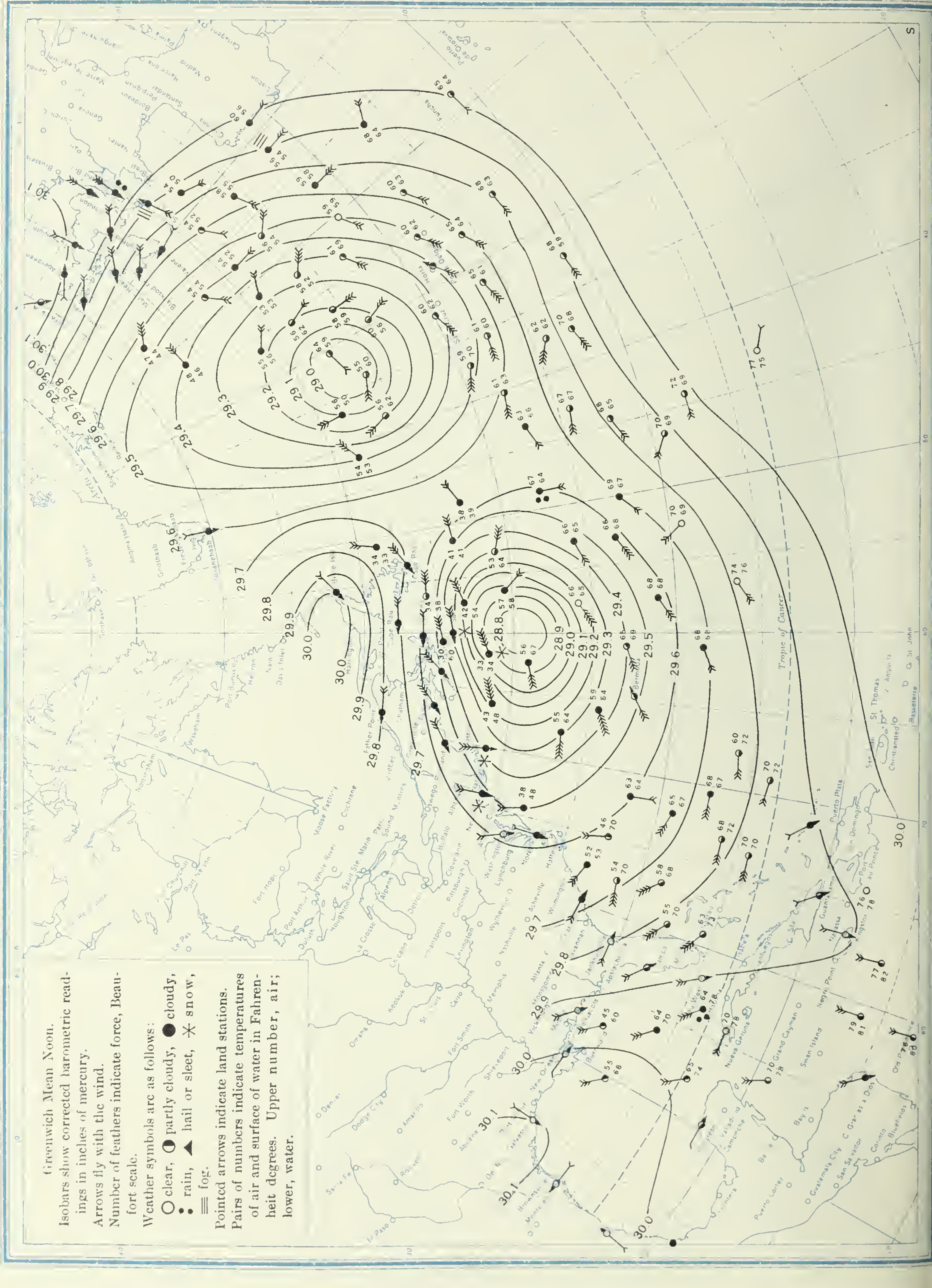


Chart XI. Weather Map of North Atlantic Ocean, March 4, 1931
(Plotted by F. A. Young)



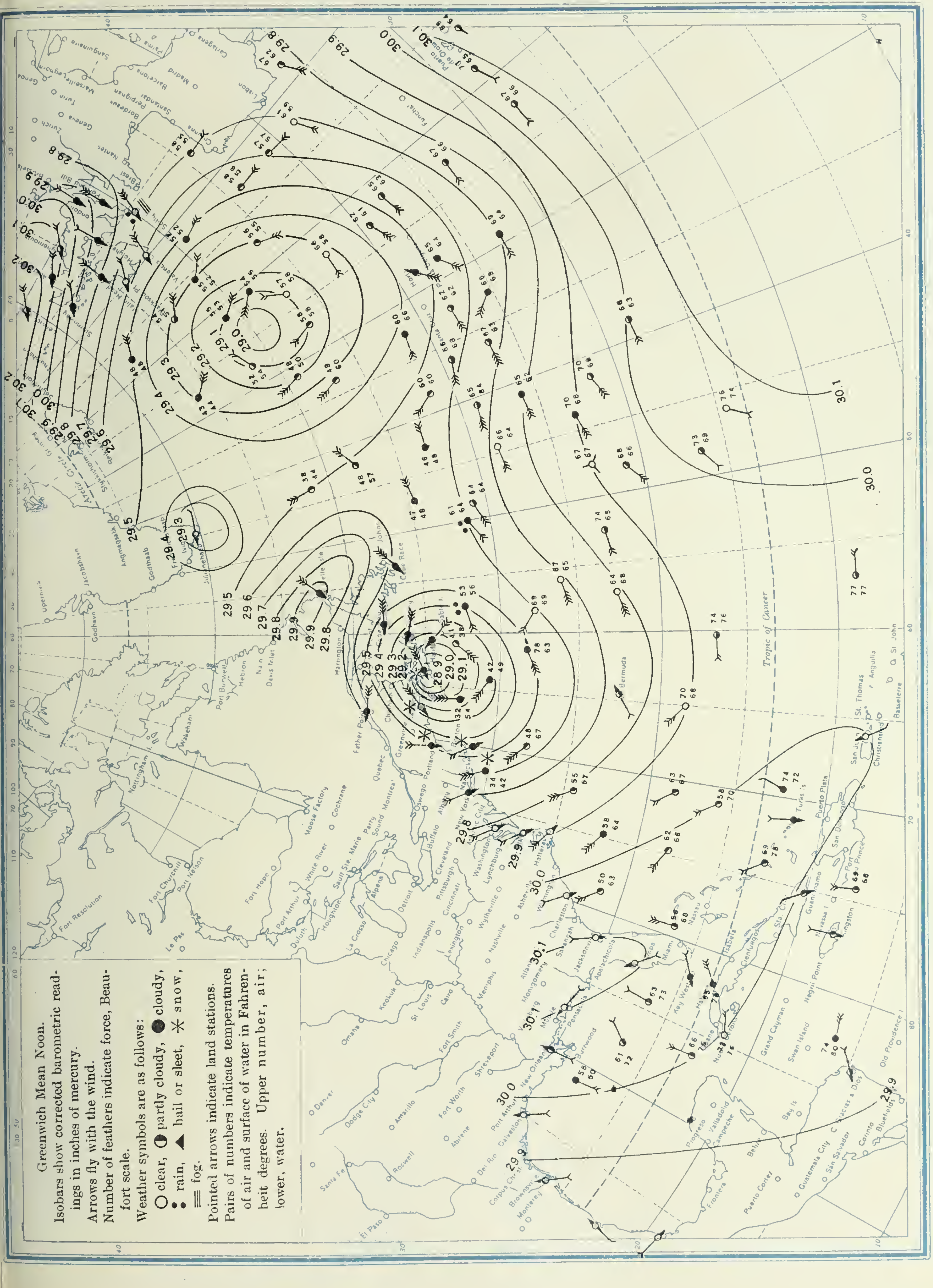
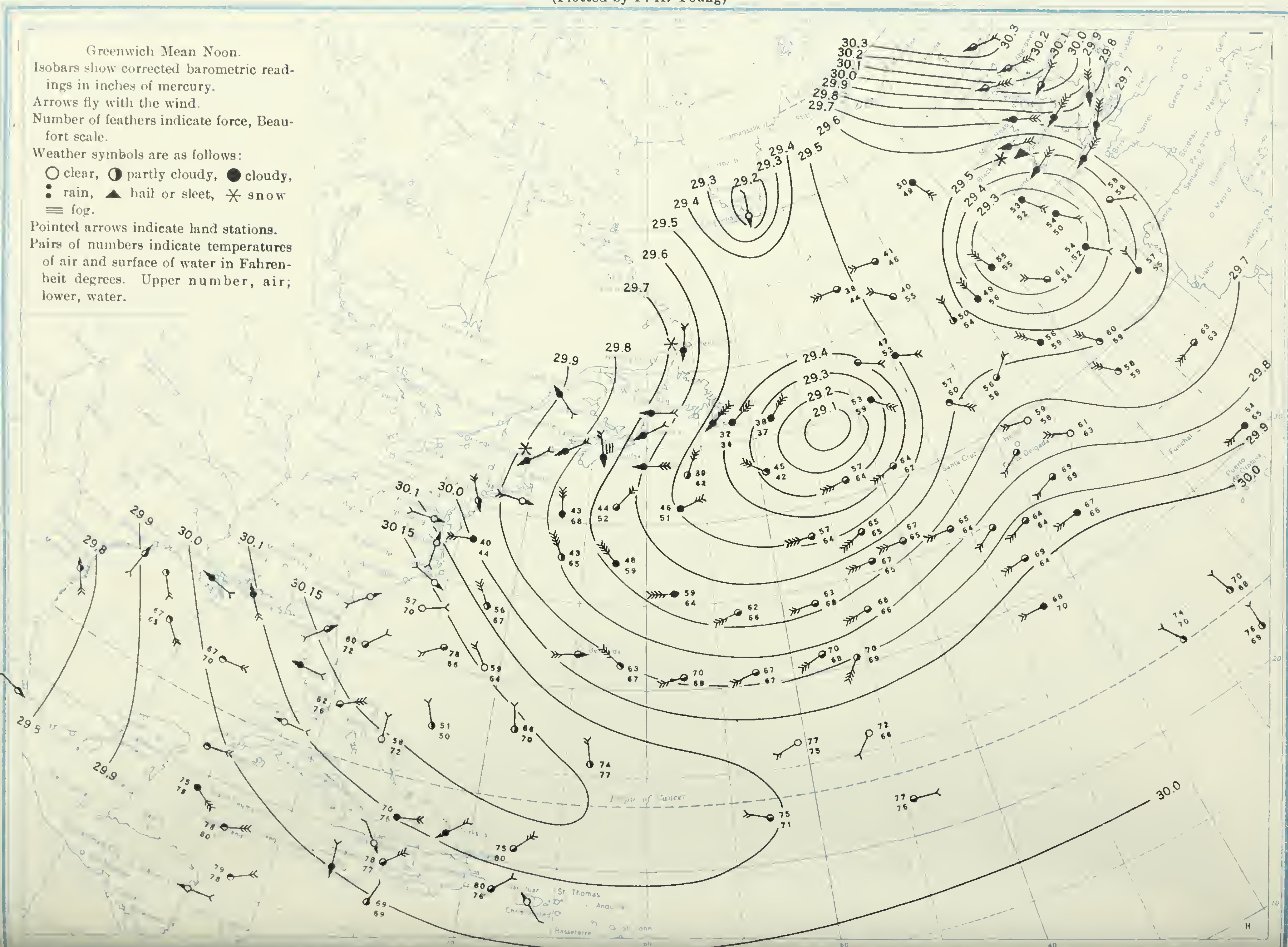

(Plotted by F. A. Young)
Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◐ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer
Arctic Circle

Chart XIII. Weather Map of North Atlantic Ocean, March 6, 1931

(Plotted by F. A. Young)



Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

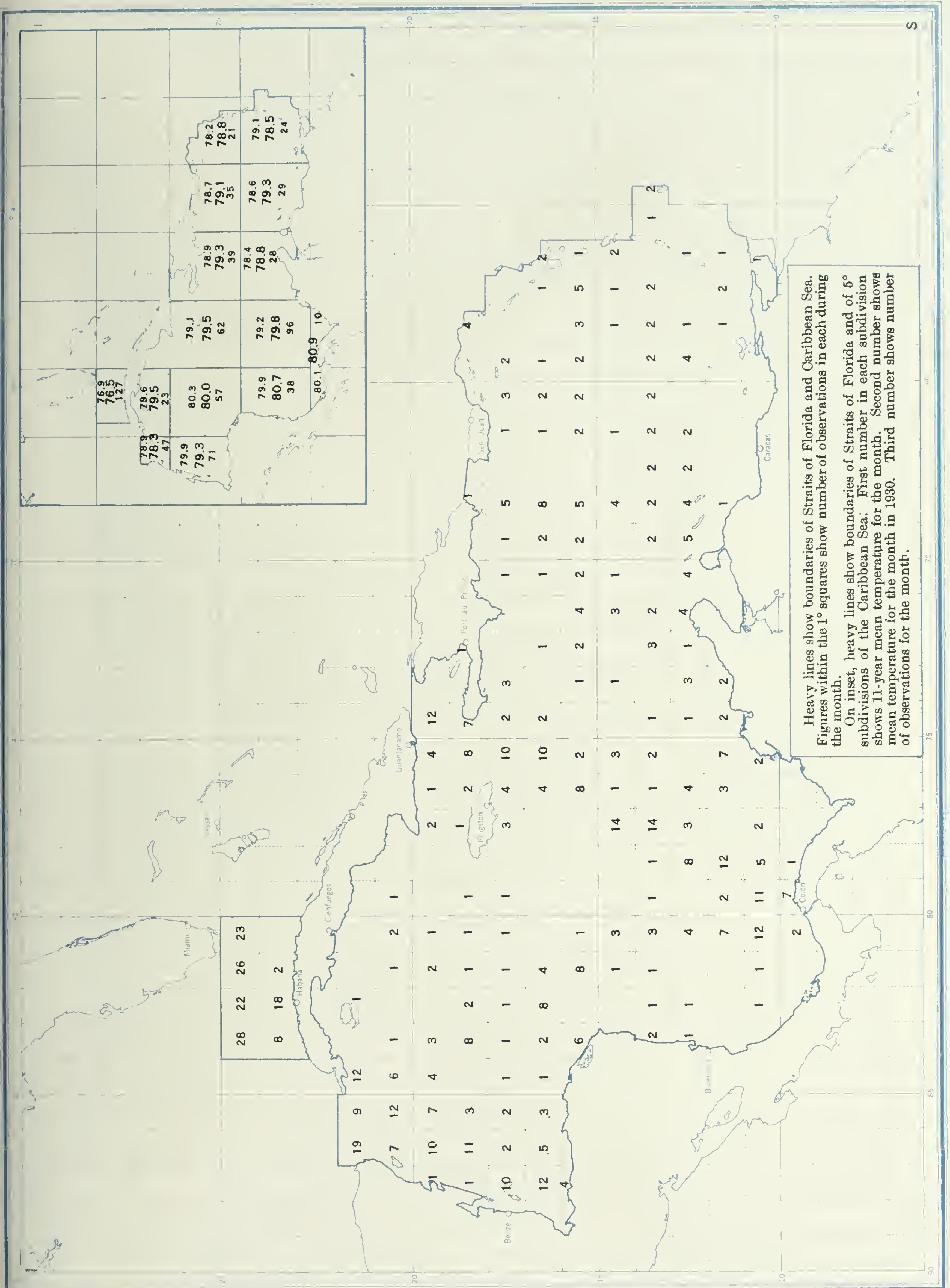
Weather symbols are as follows:

○ clear, ◐ partly cloudy, ● cloudy, : rain, ▲ hail or sleet, ✳ snow ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, April, 1930



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, April, 1931

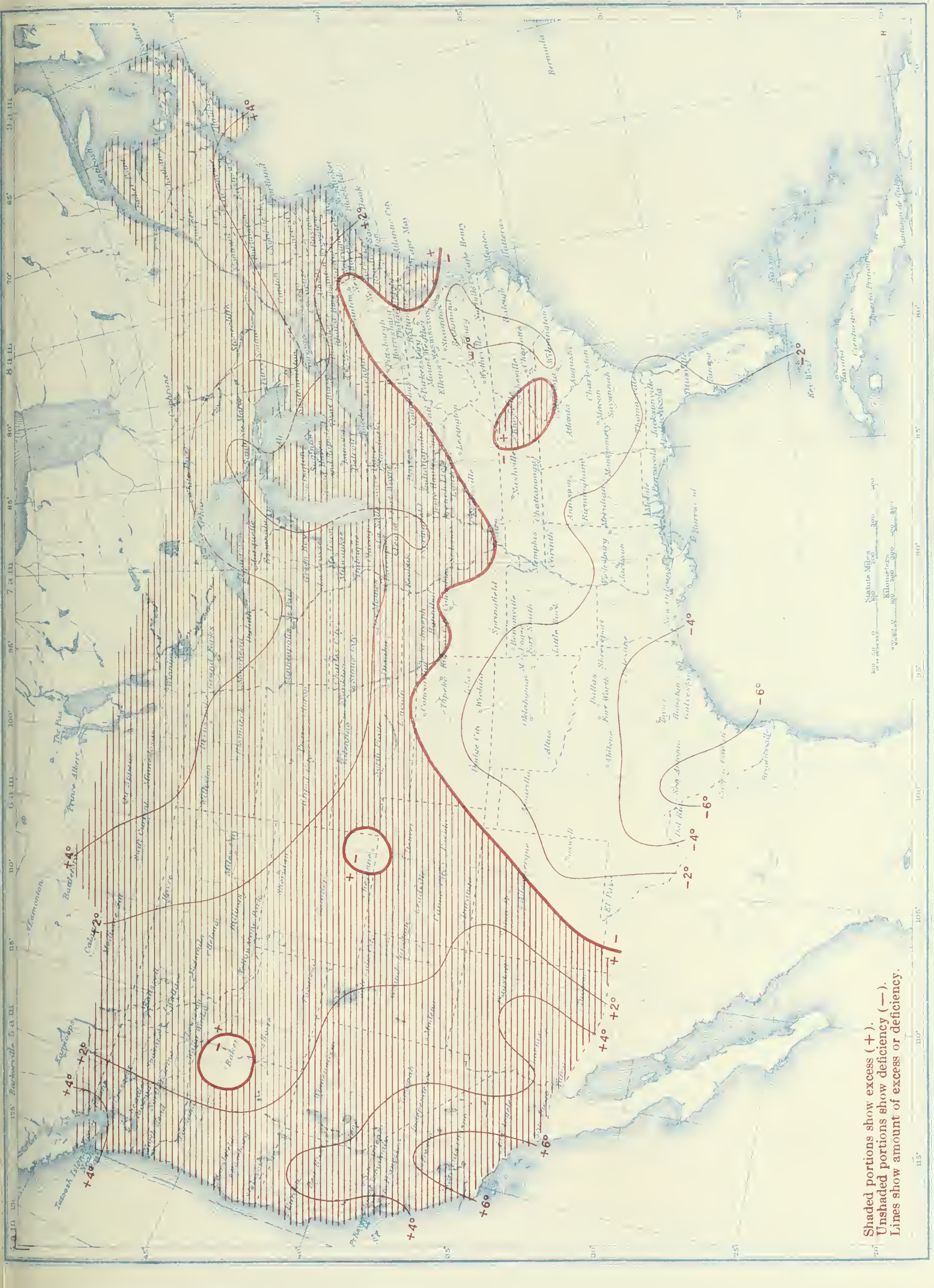
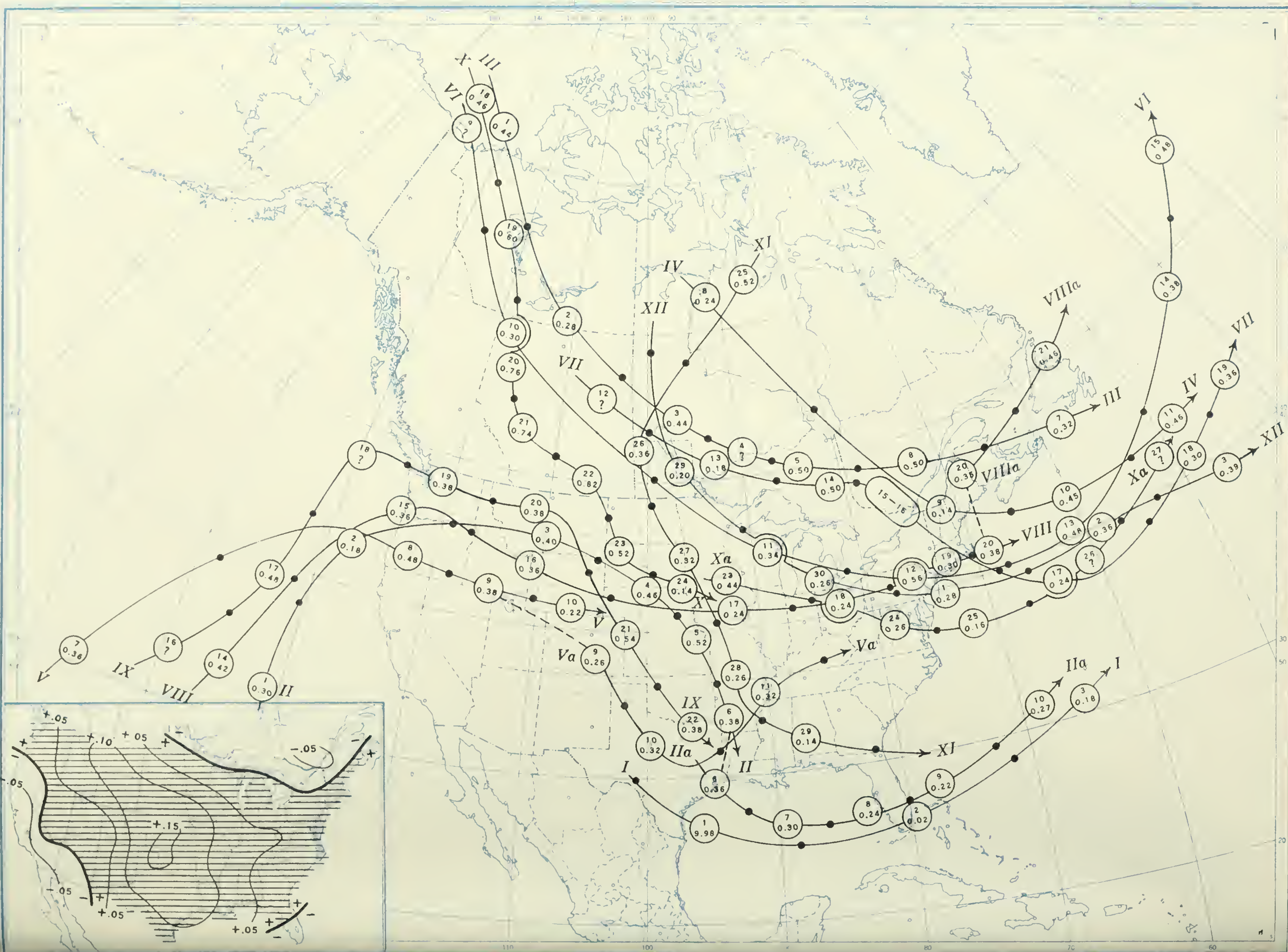
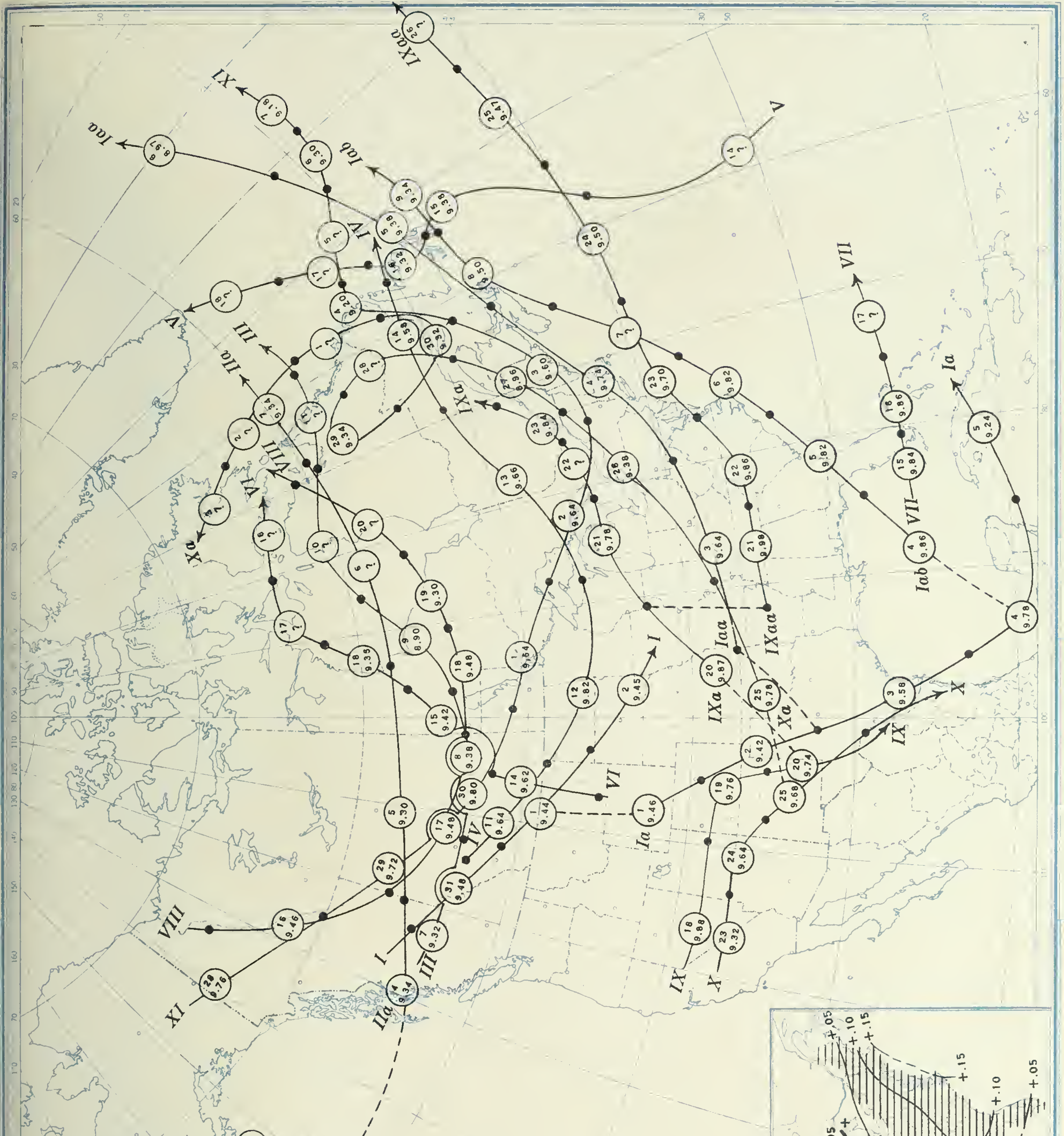


Chart II. Tracks of Centers of Anticyclones, April, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)

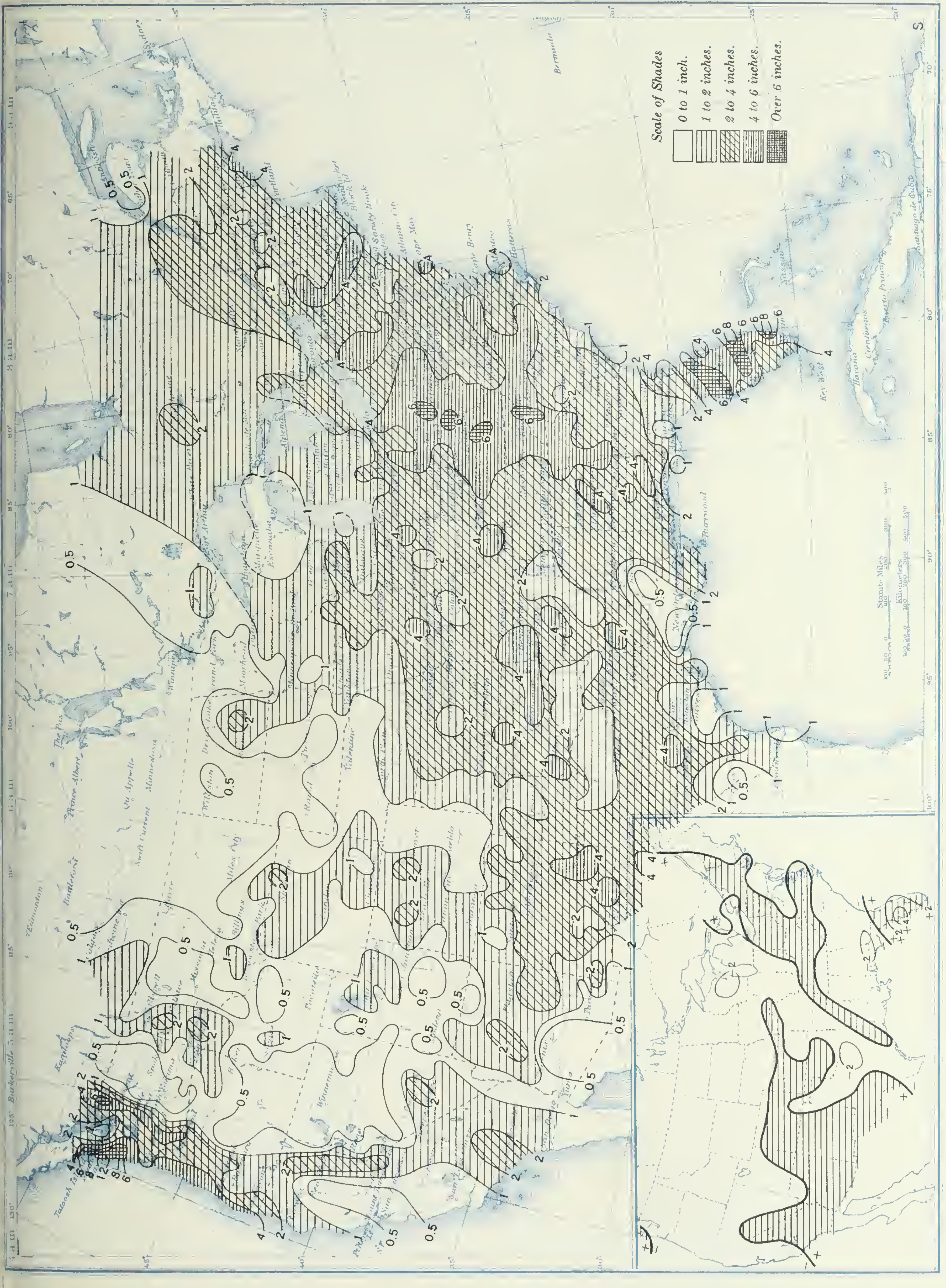




Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, April, 1931

Chart V. Total Precipitation, Inches, April, 1931. (Inset) Departure of Precipitation from Normal



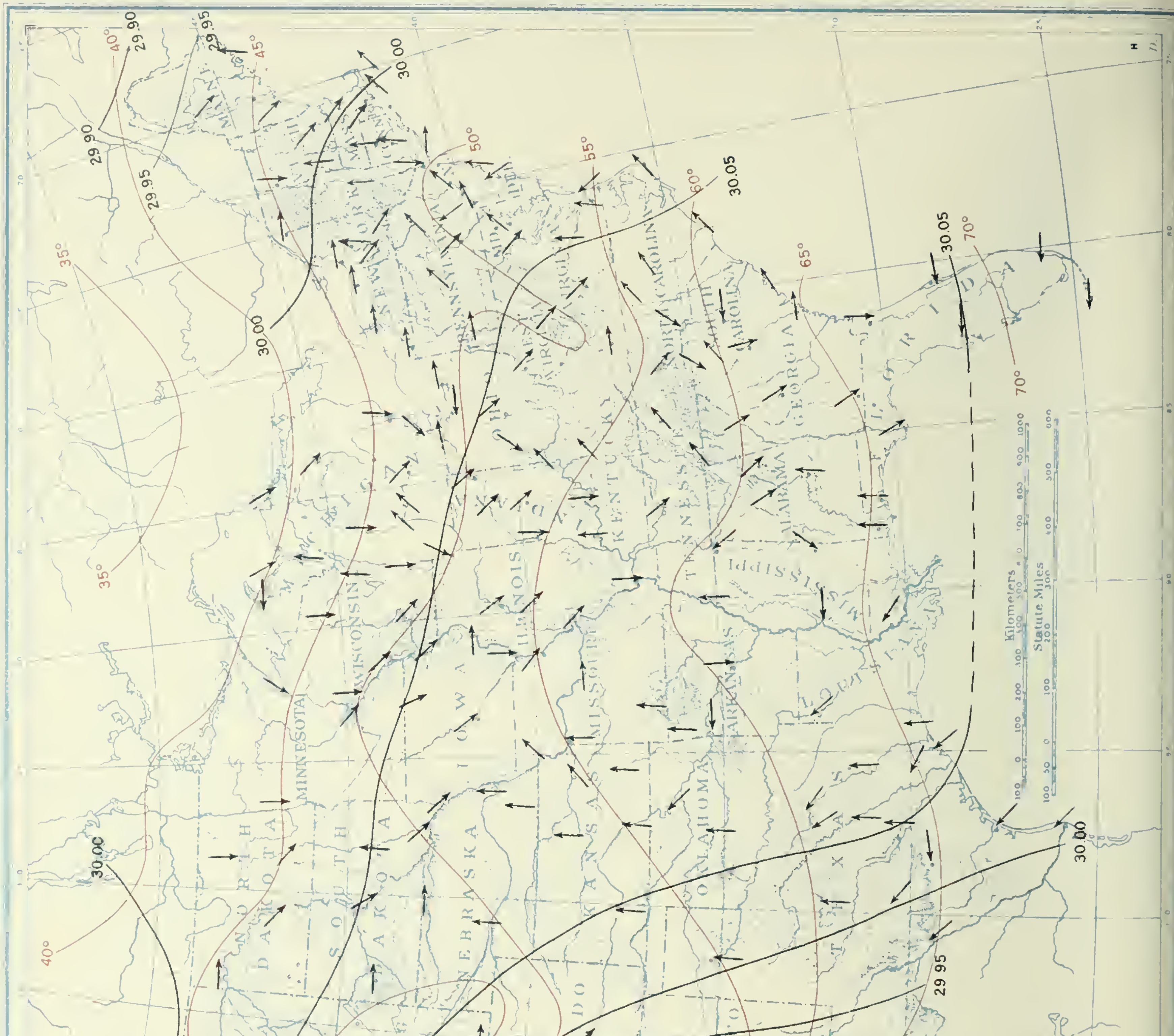
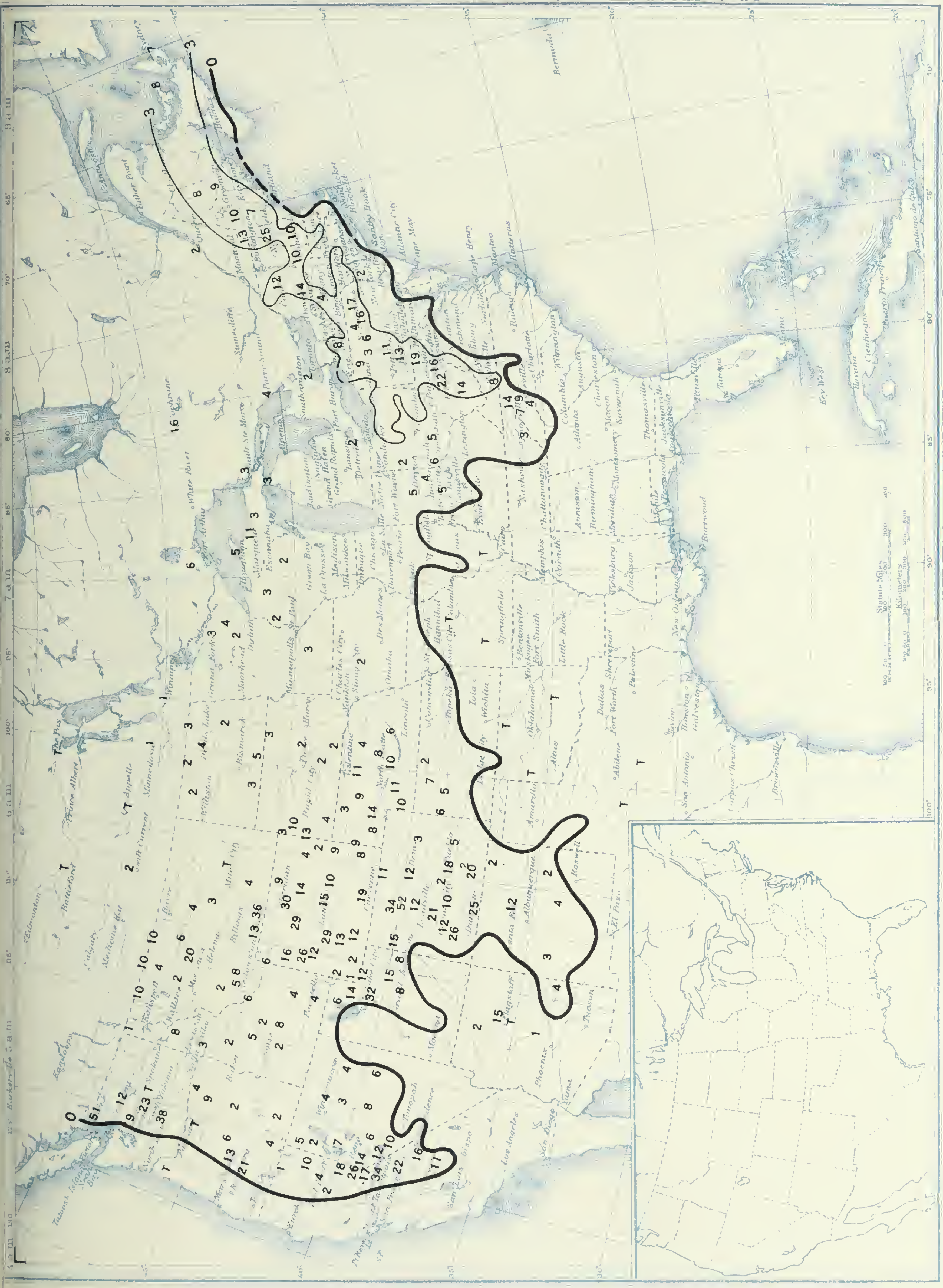


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, April, 1931



(Plotted by F. A. Young)

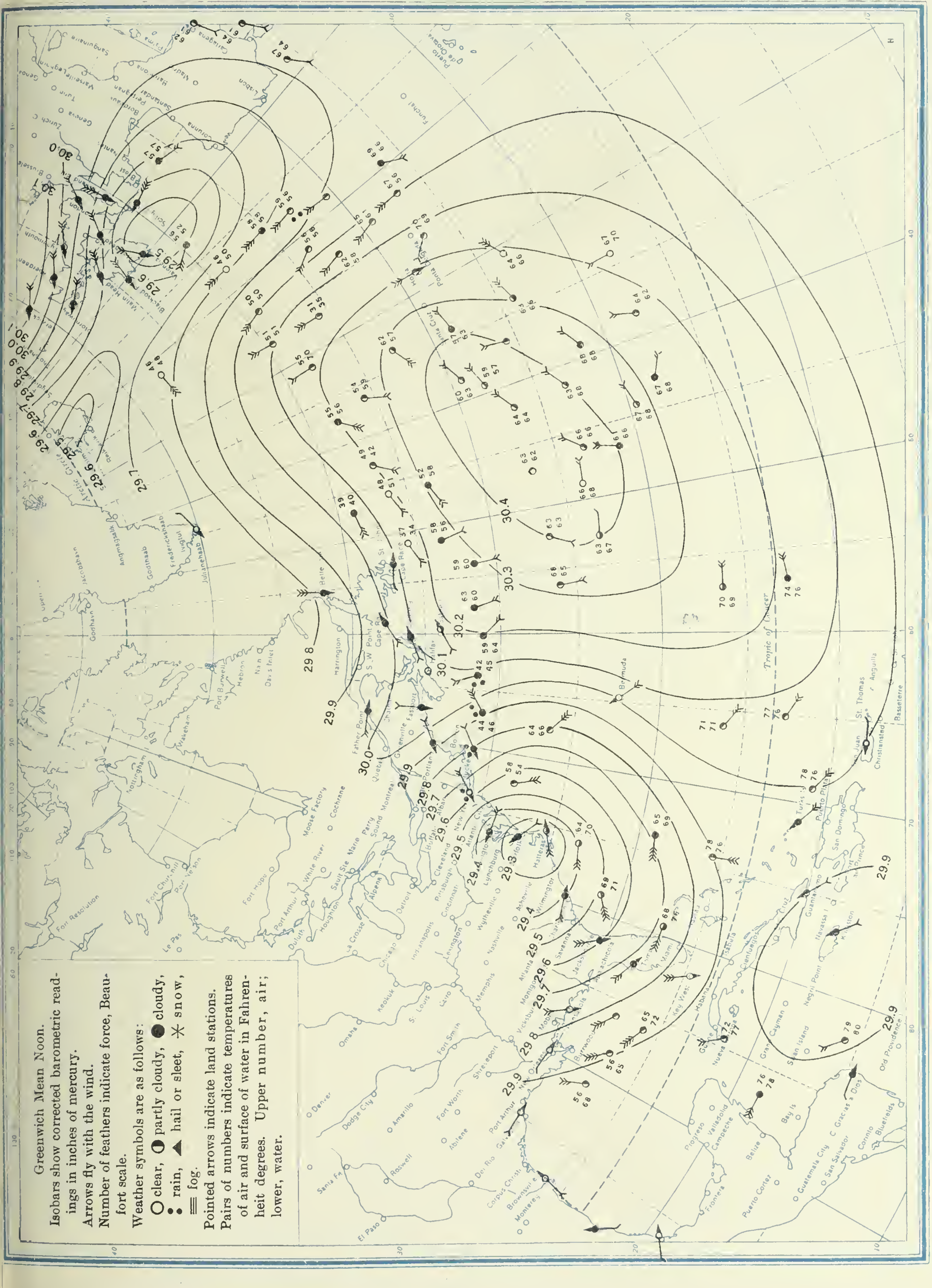
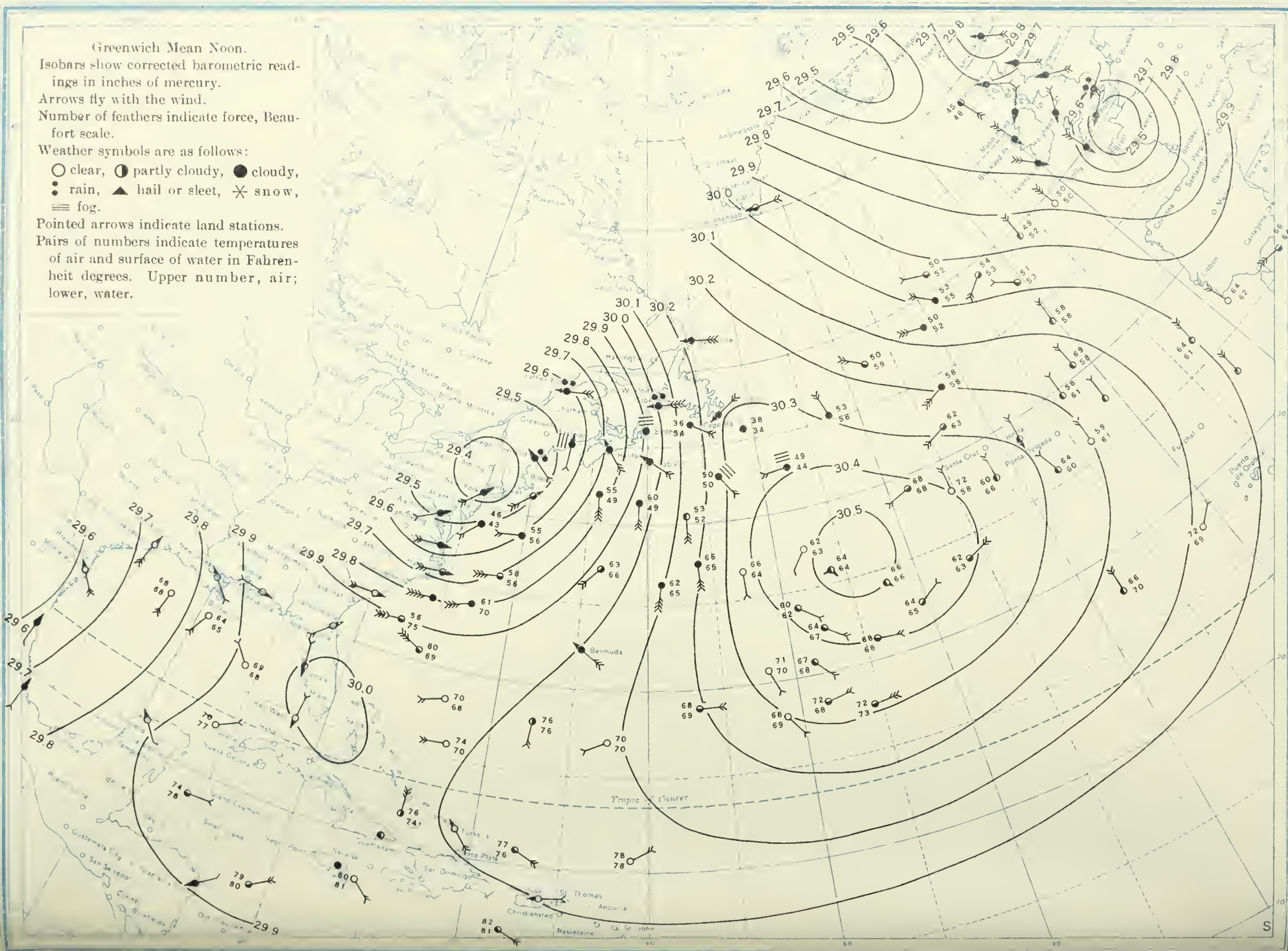


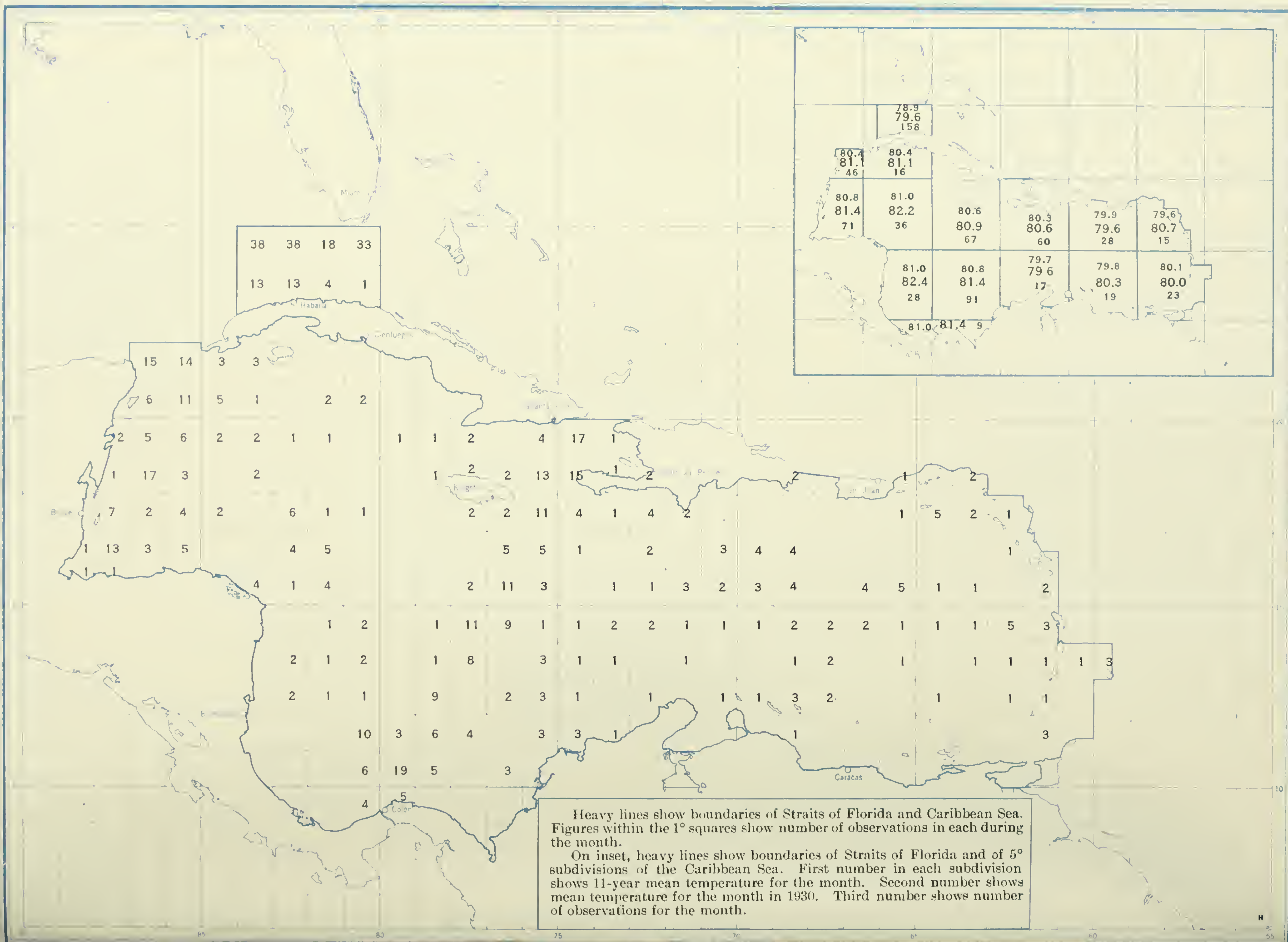
Chart IX. Weather Map of North Atlantic Ocean, April 2, 1931

(Plotted by F. A. Young)



Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, May, 1930

(Plotted by Giles Slocum)



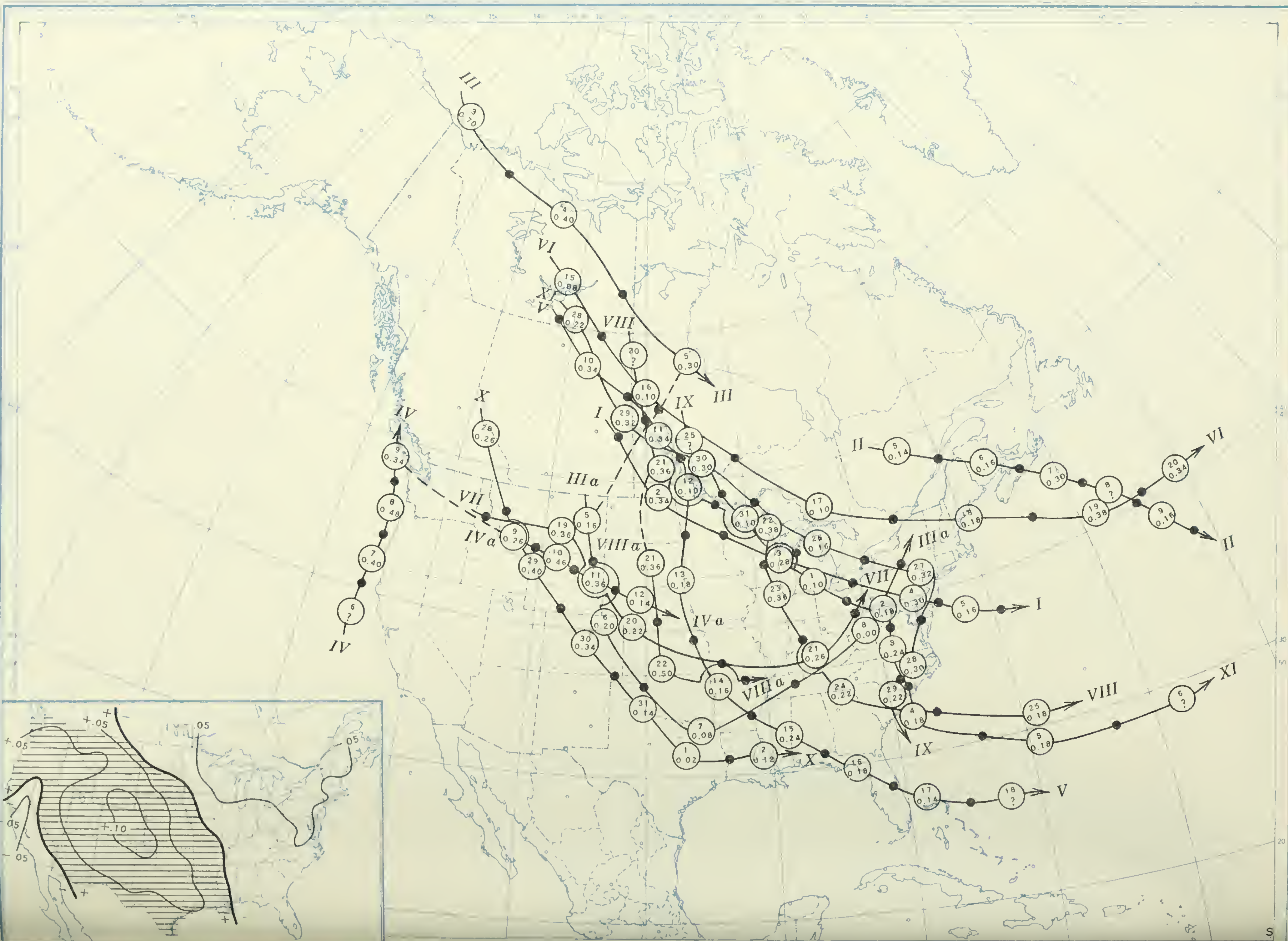
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

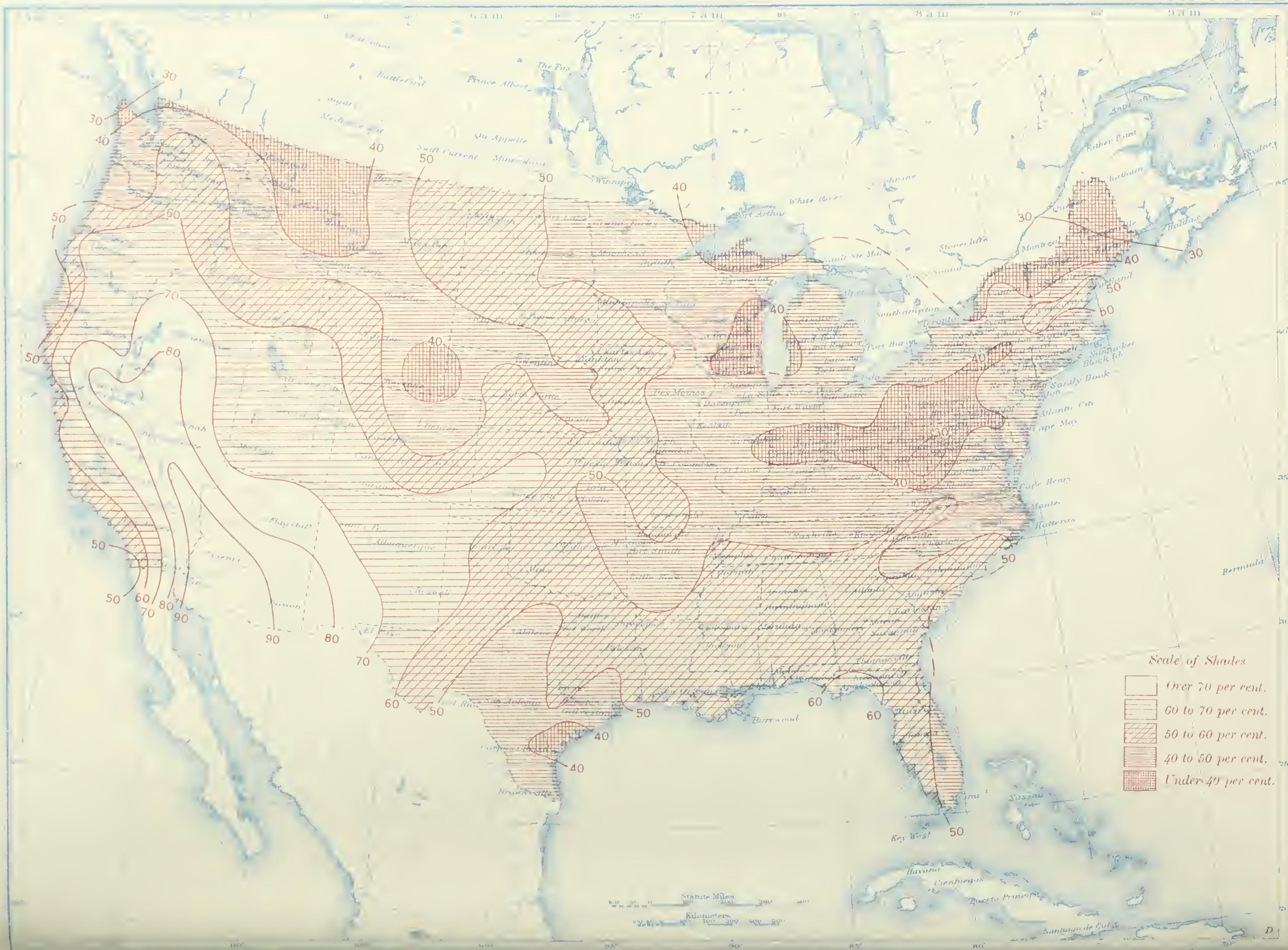
Chart II. Tracks of Centers of Anticyclones, May, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

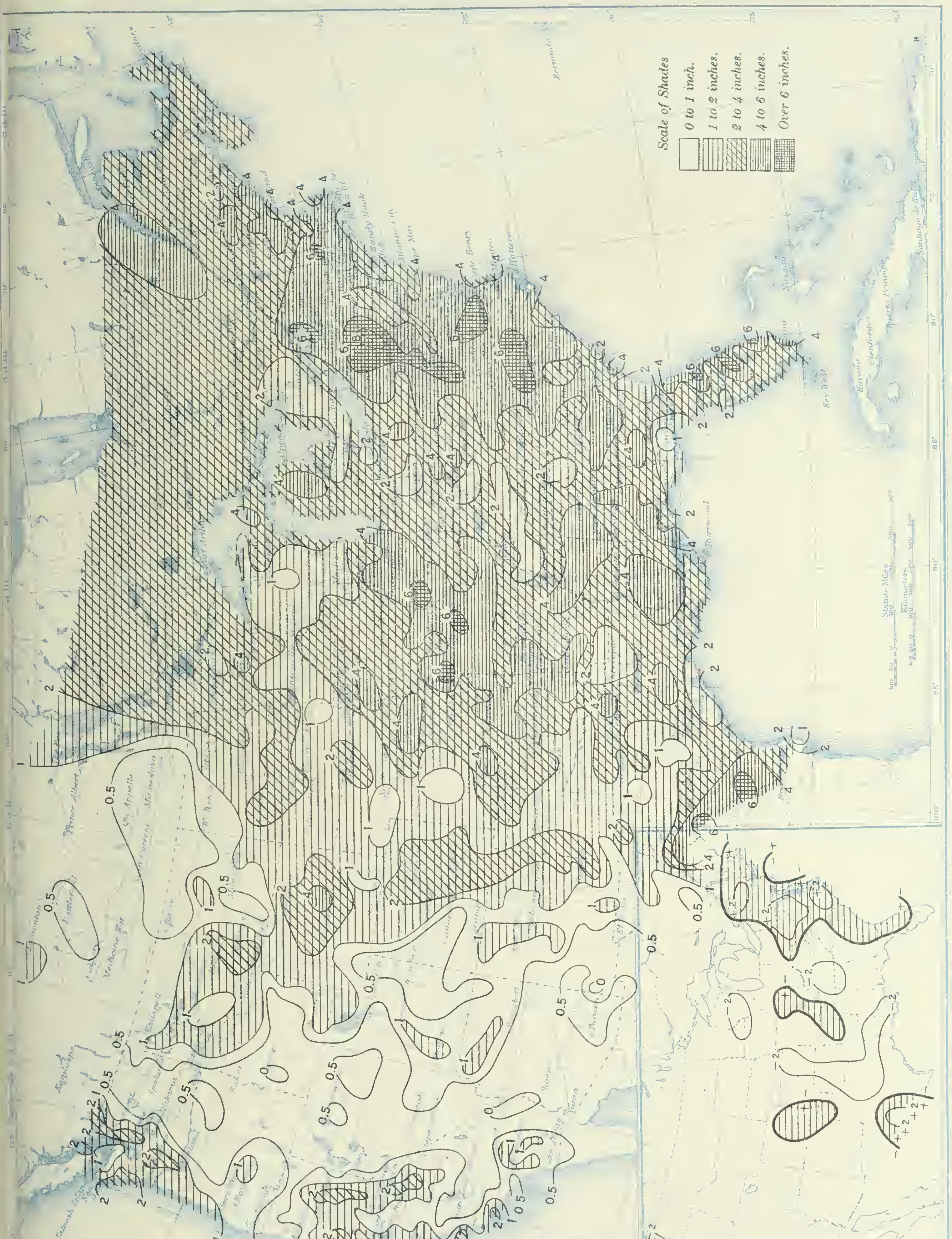
(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, May, 1931




Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.

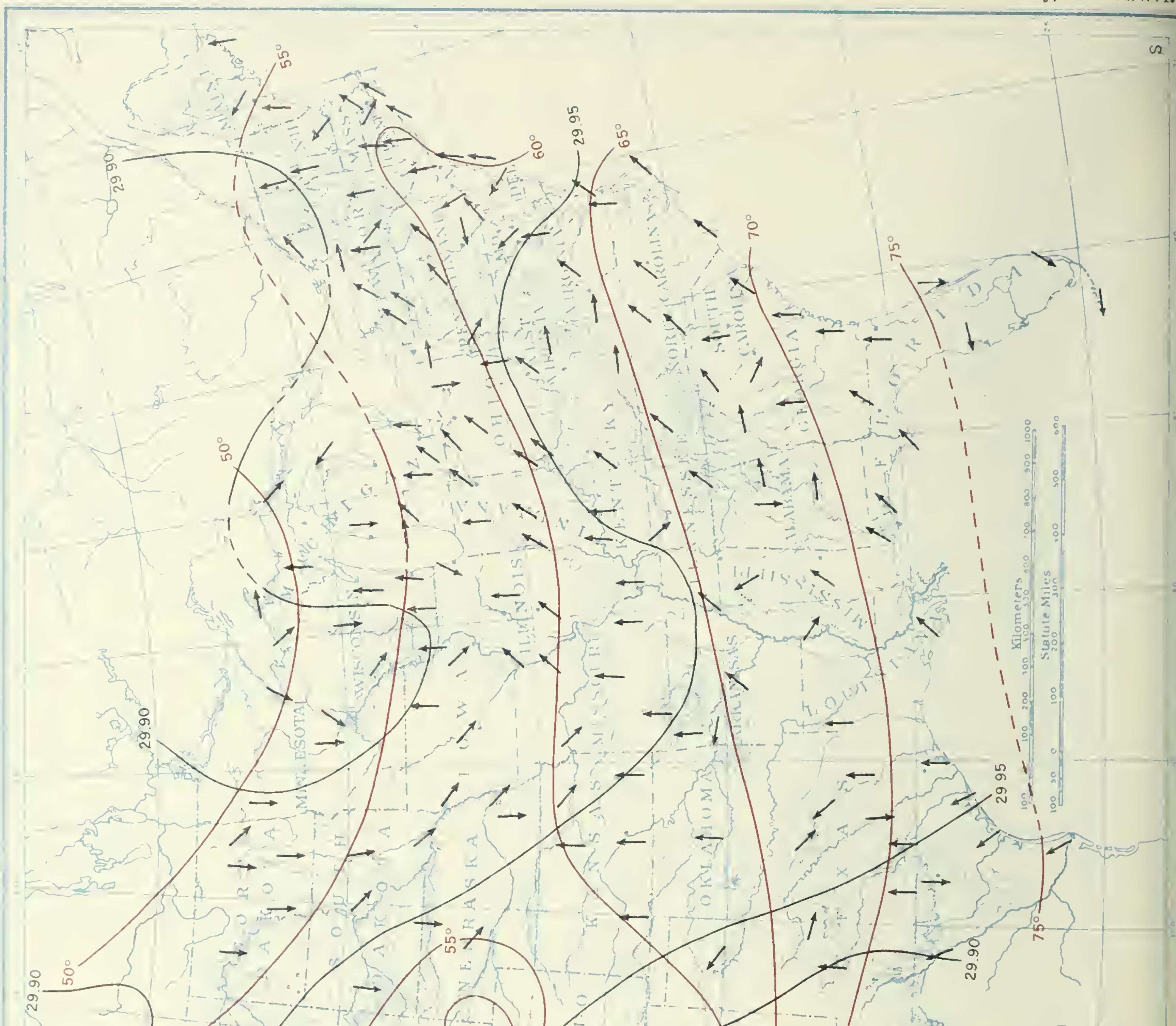


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, May, 1931

(Plotted by F. A. Young)

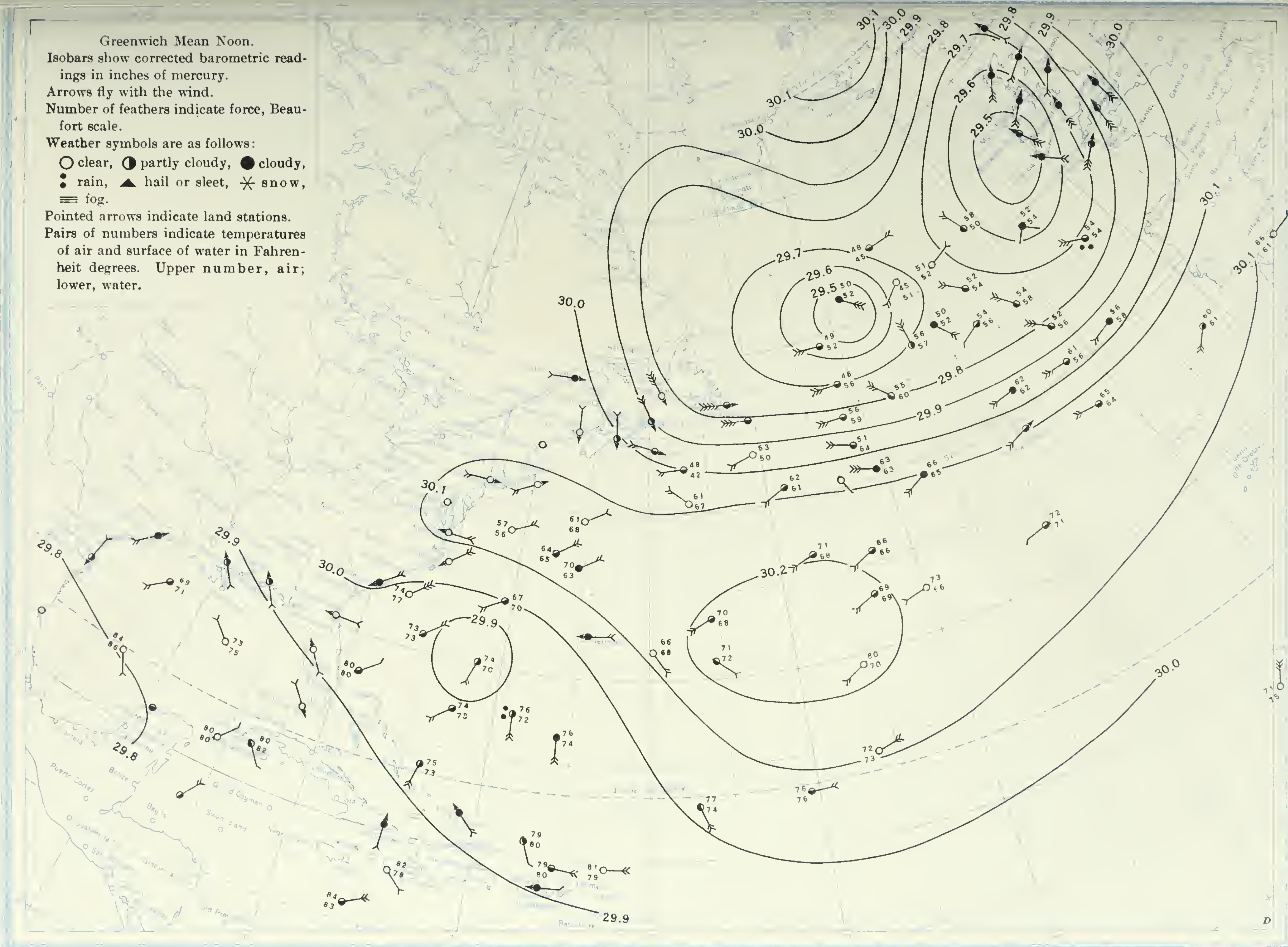


Chart IX. Weather Map of North Atlantic Ocean, May 6, 1931

(Plotted by F. A. Young)

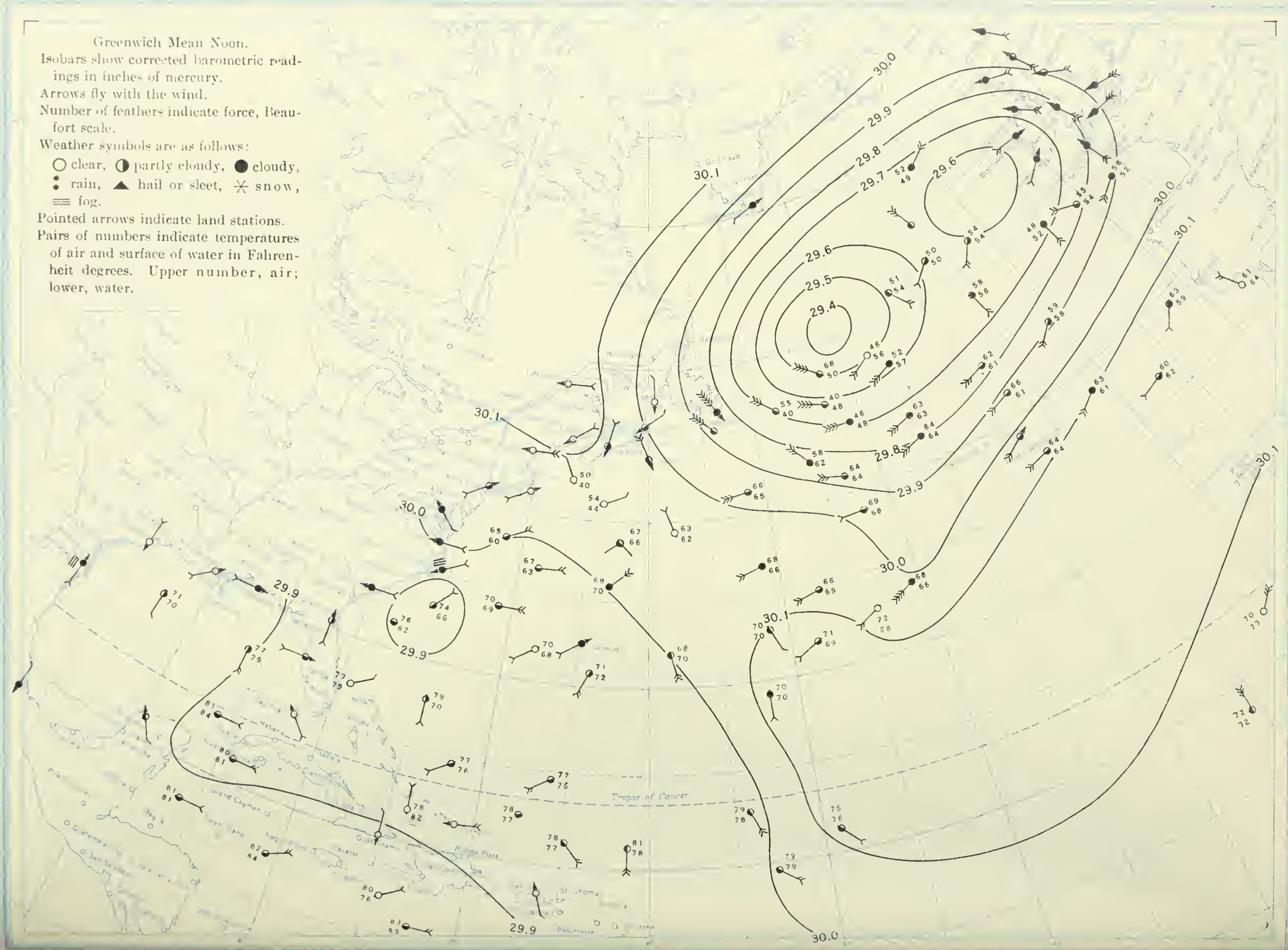


Chart X. Weather Map of North Atlantic Ocean, May 1, 1931

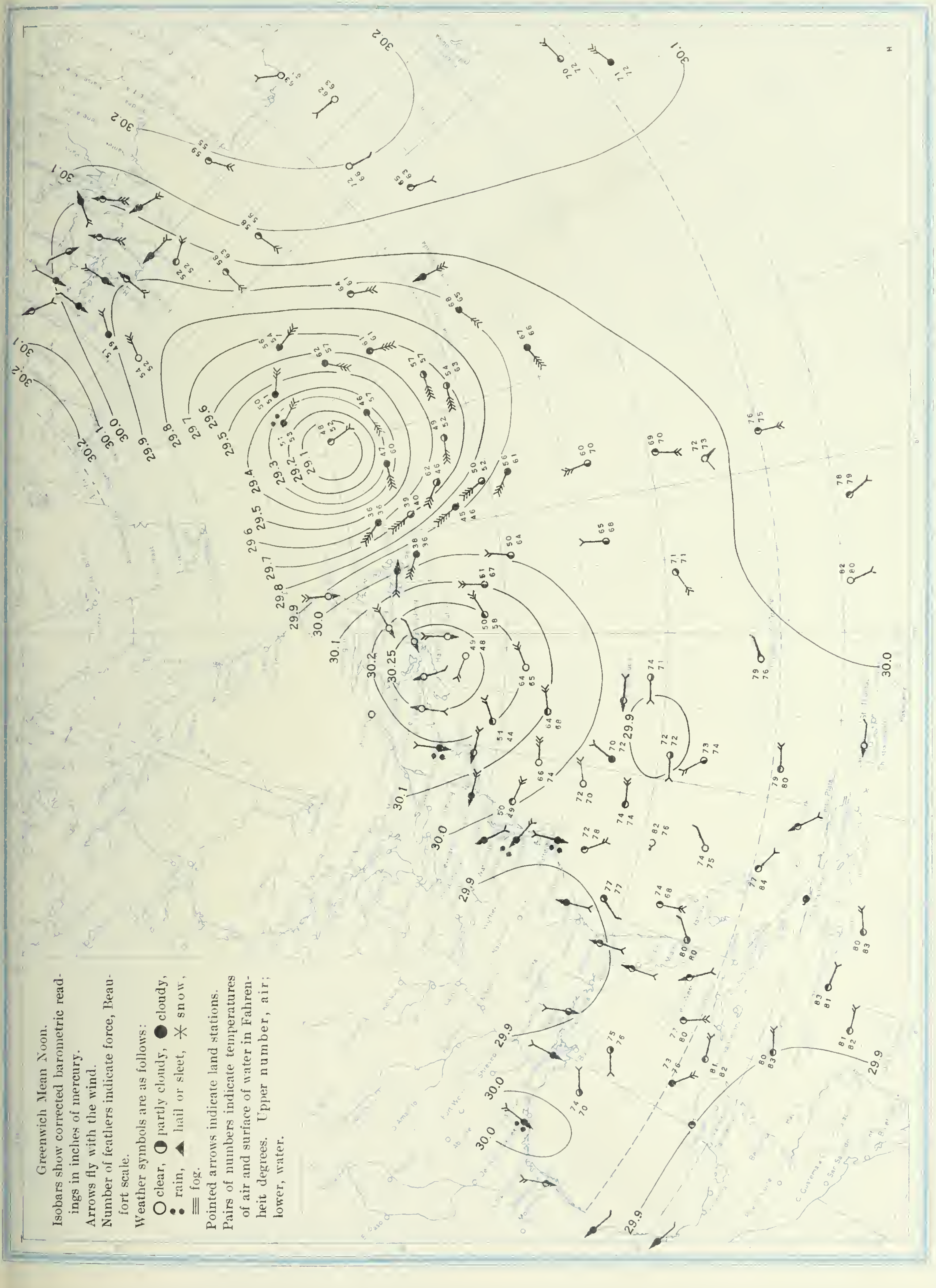


Chart XI. Weather Map of North Atlantic Ocean, May 8, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

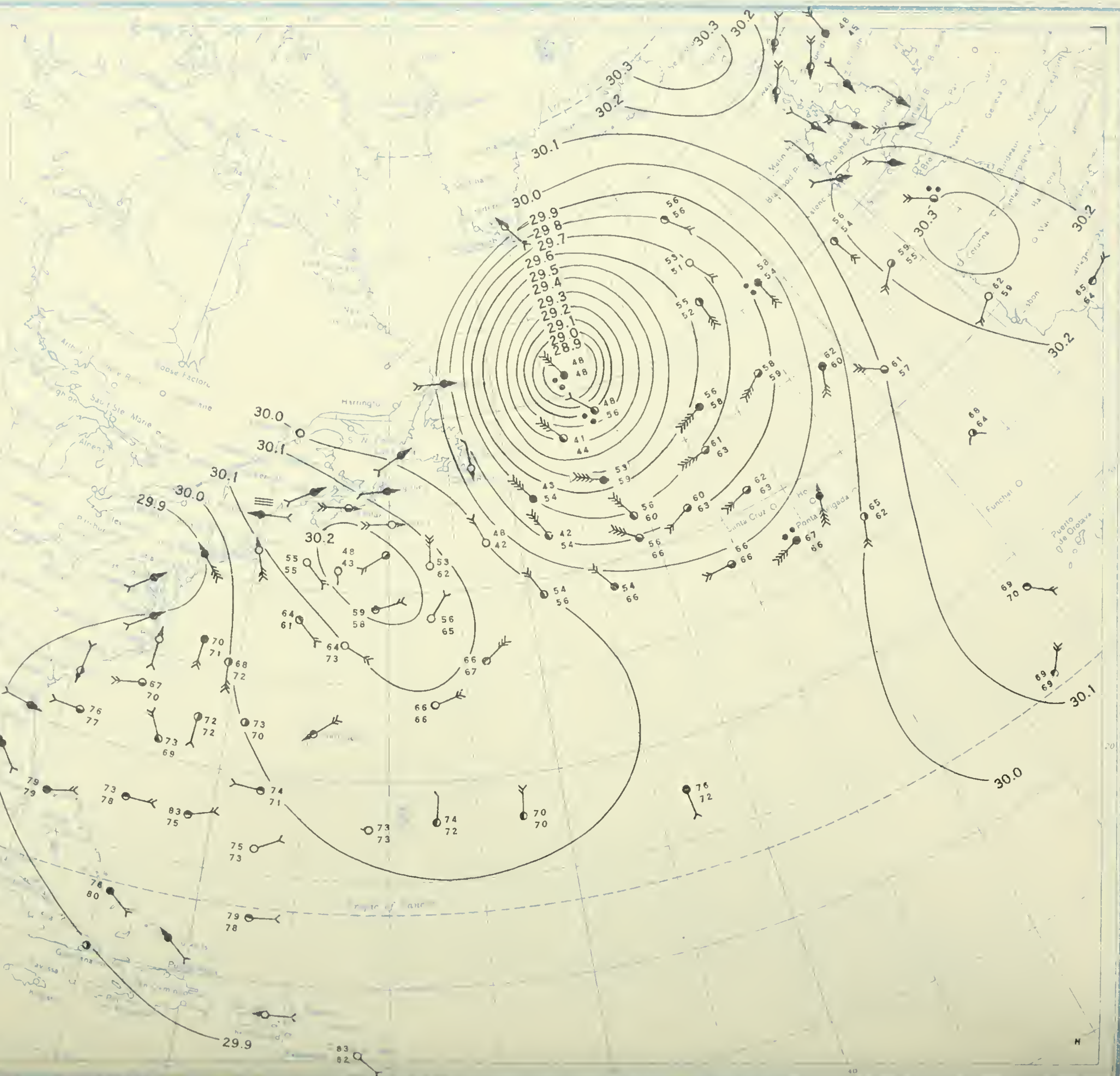
Number of feathers indicate force, Beaufort scale.

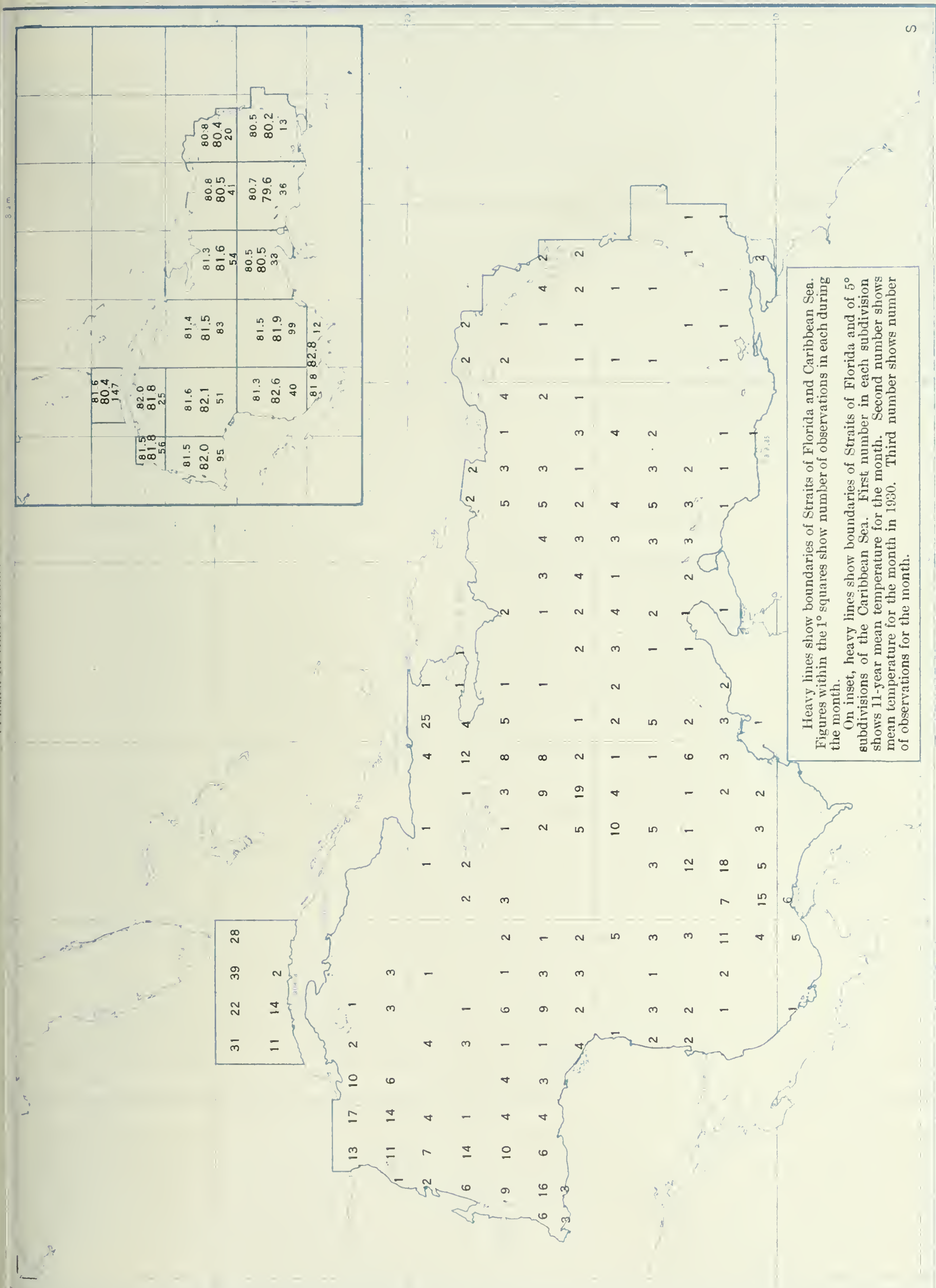
Weather symbols are as follows:

○ clear, ◐ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.





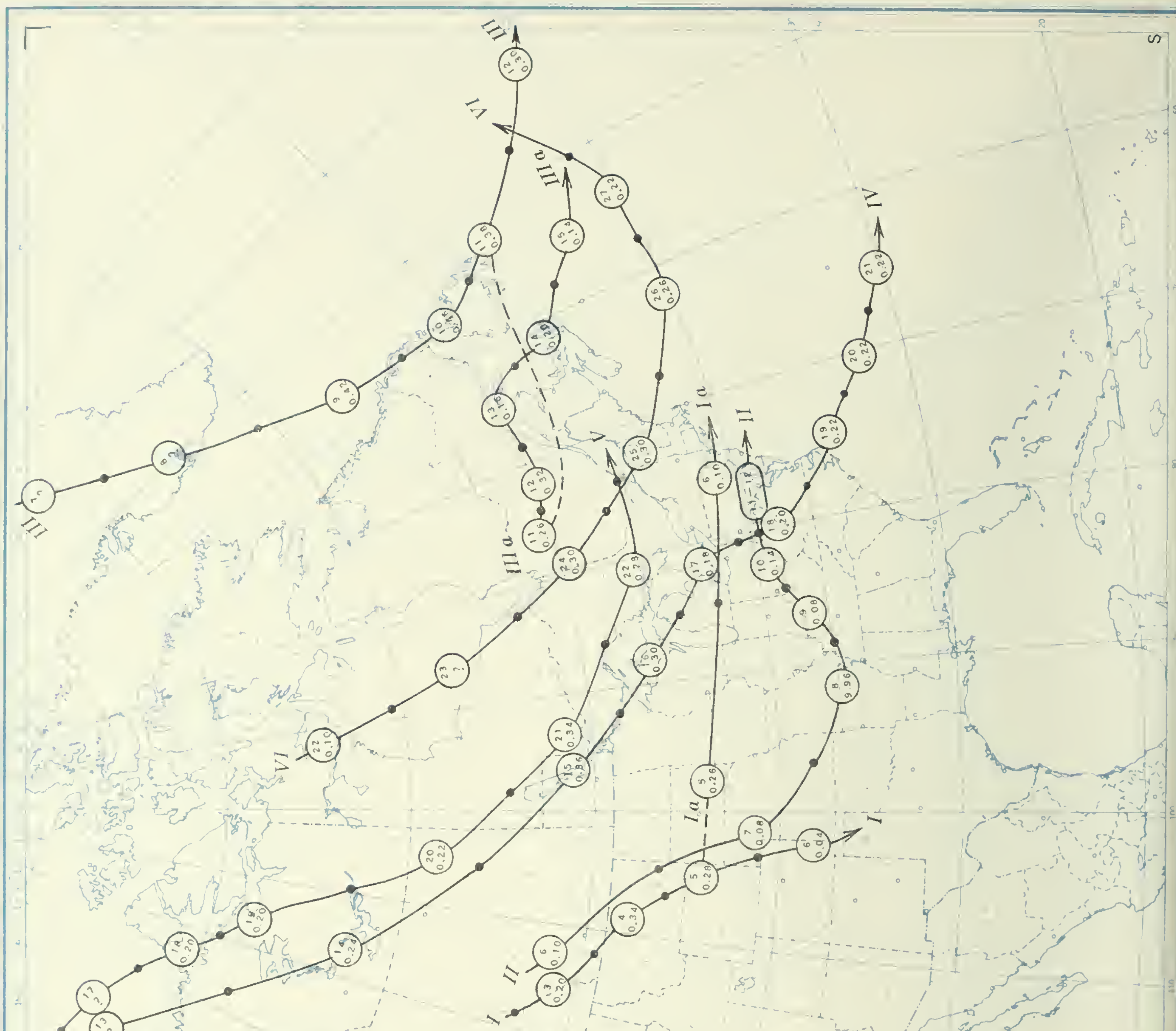
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
+2°
+4°
+6°
+8°

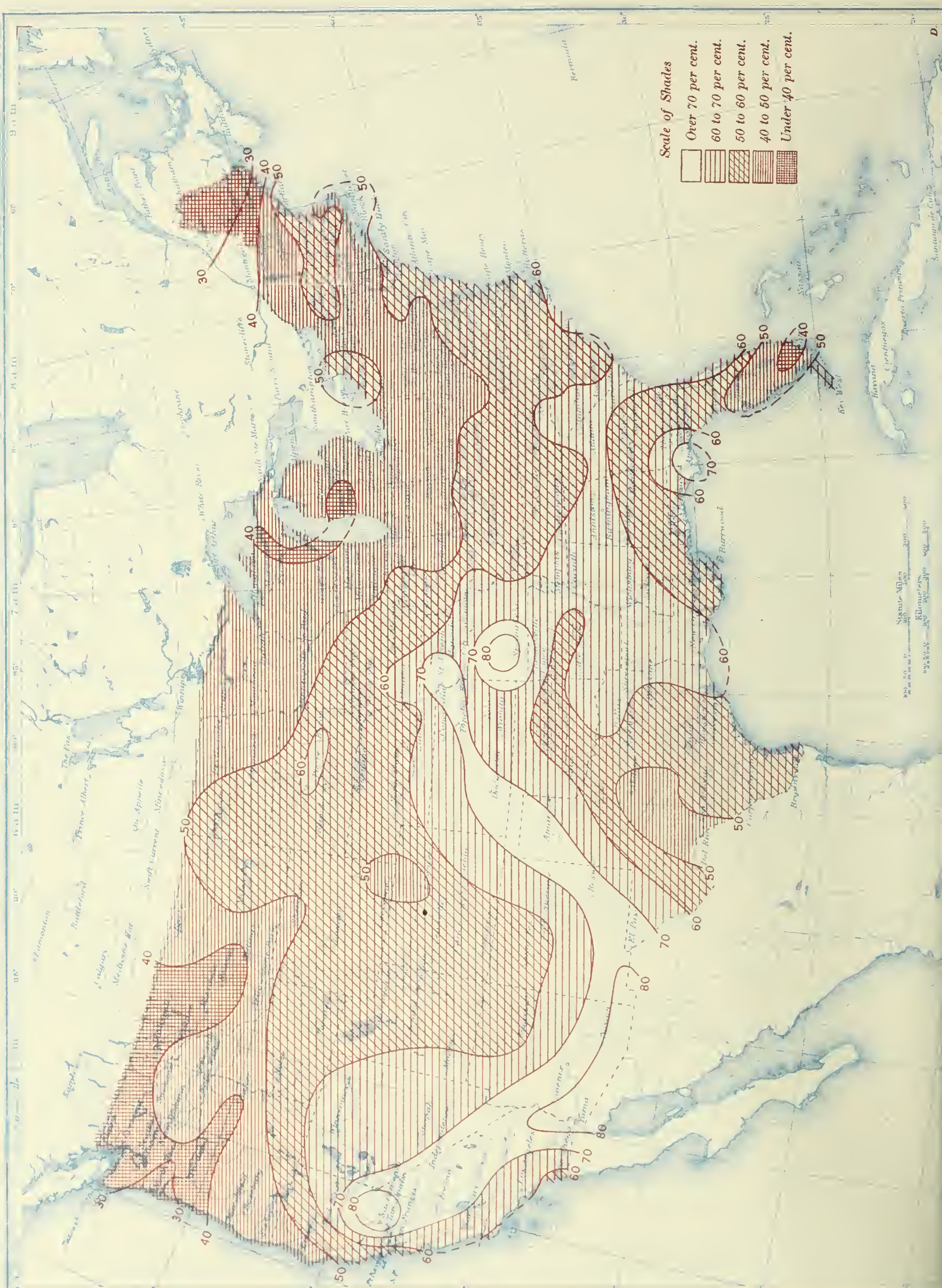
Chart II. Tracks of Centers of Anticyclones, June, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by C. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, June, 1931



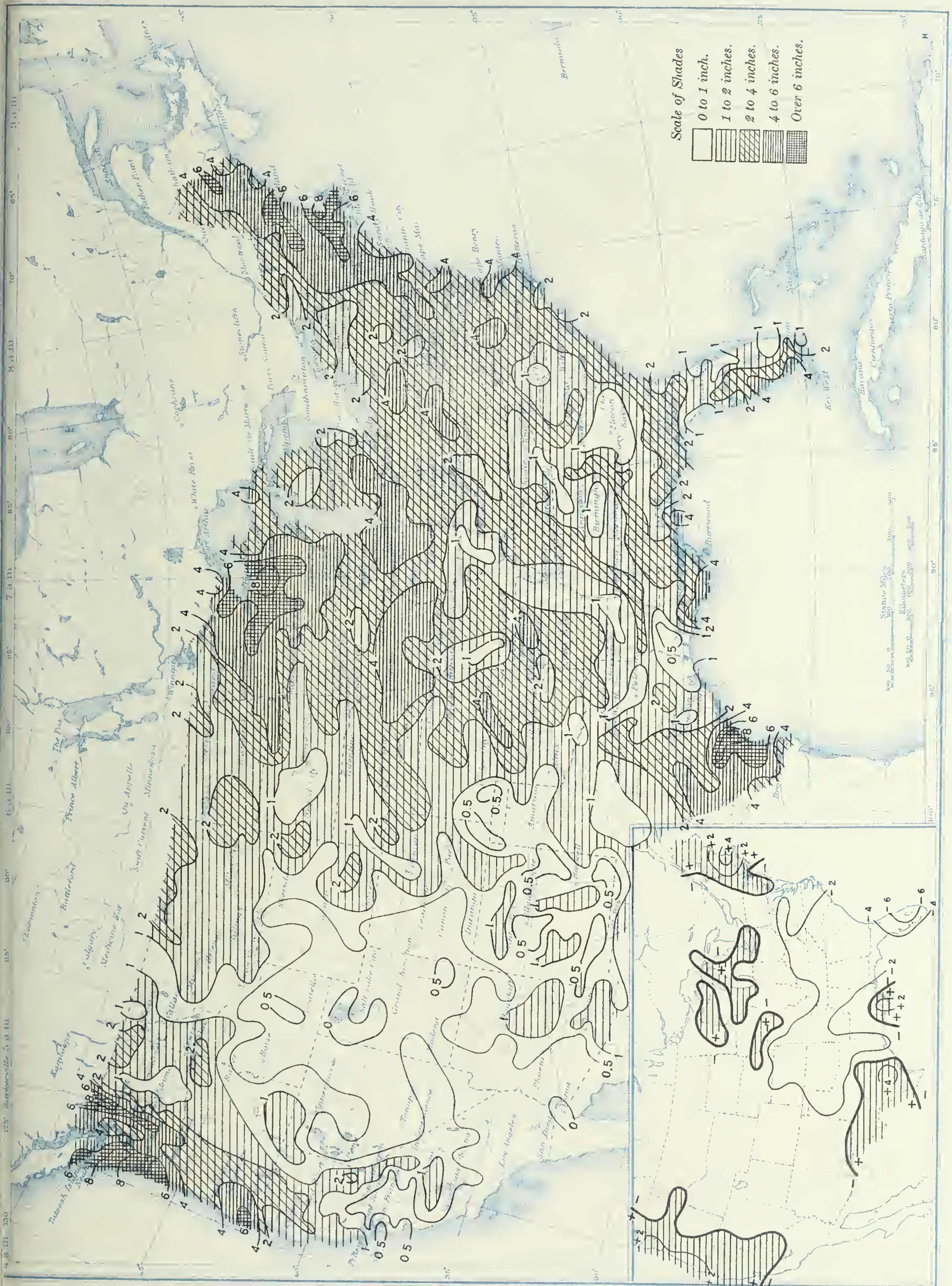

Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.
Statute Miles
Kilometers

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, June, 1931

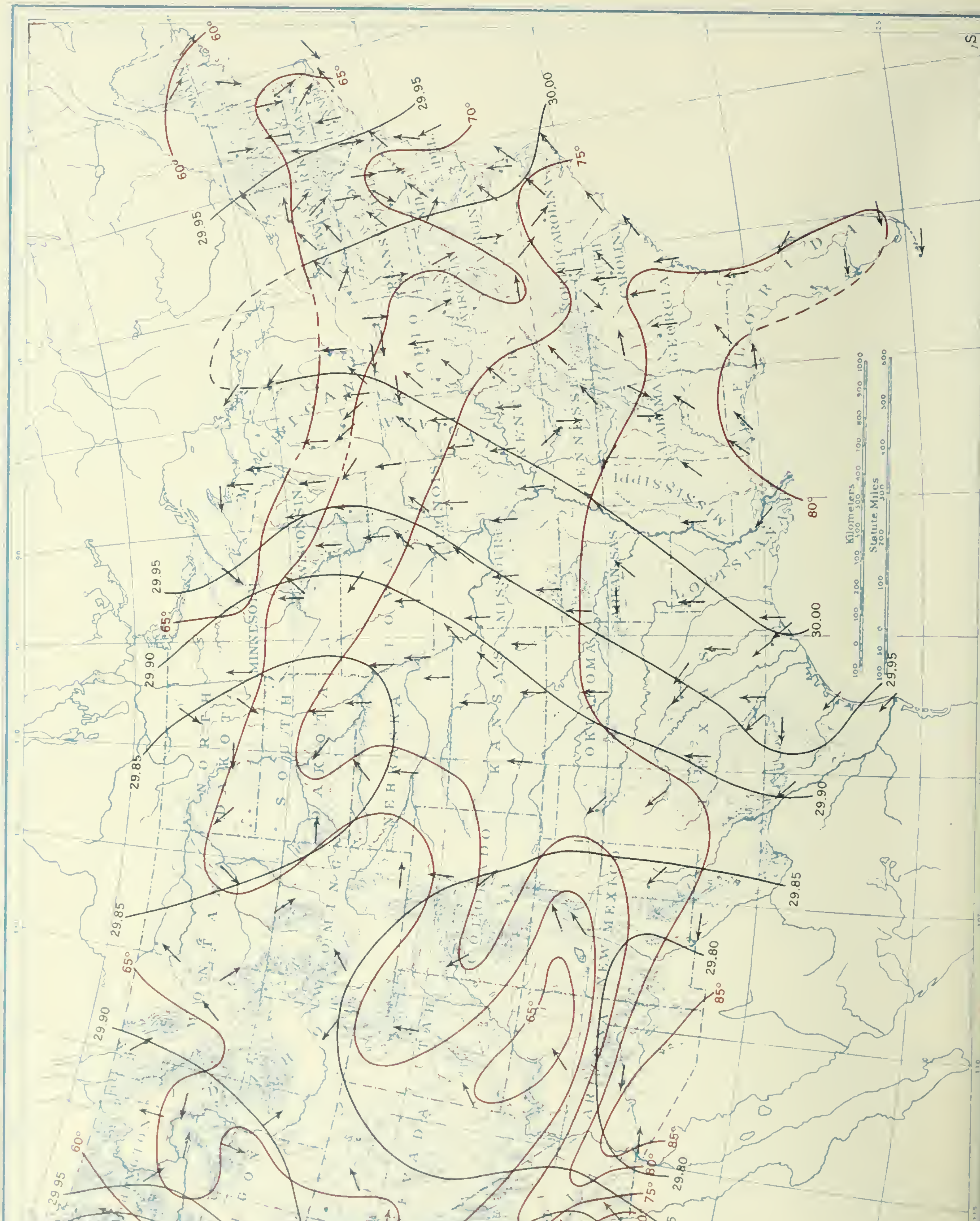


Chart VIII. Weather Map of North Atlantic Ocean, June 23, 1931

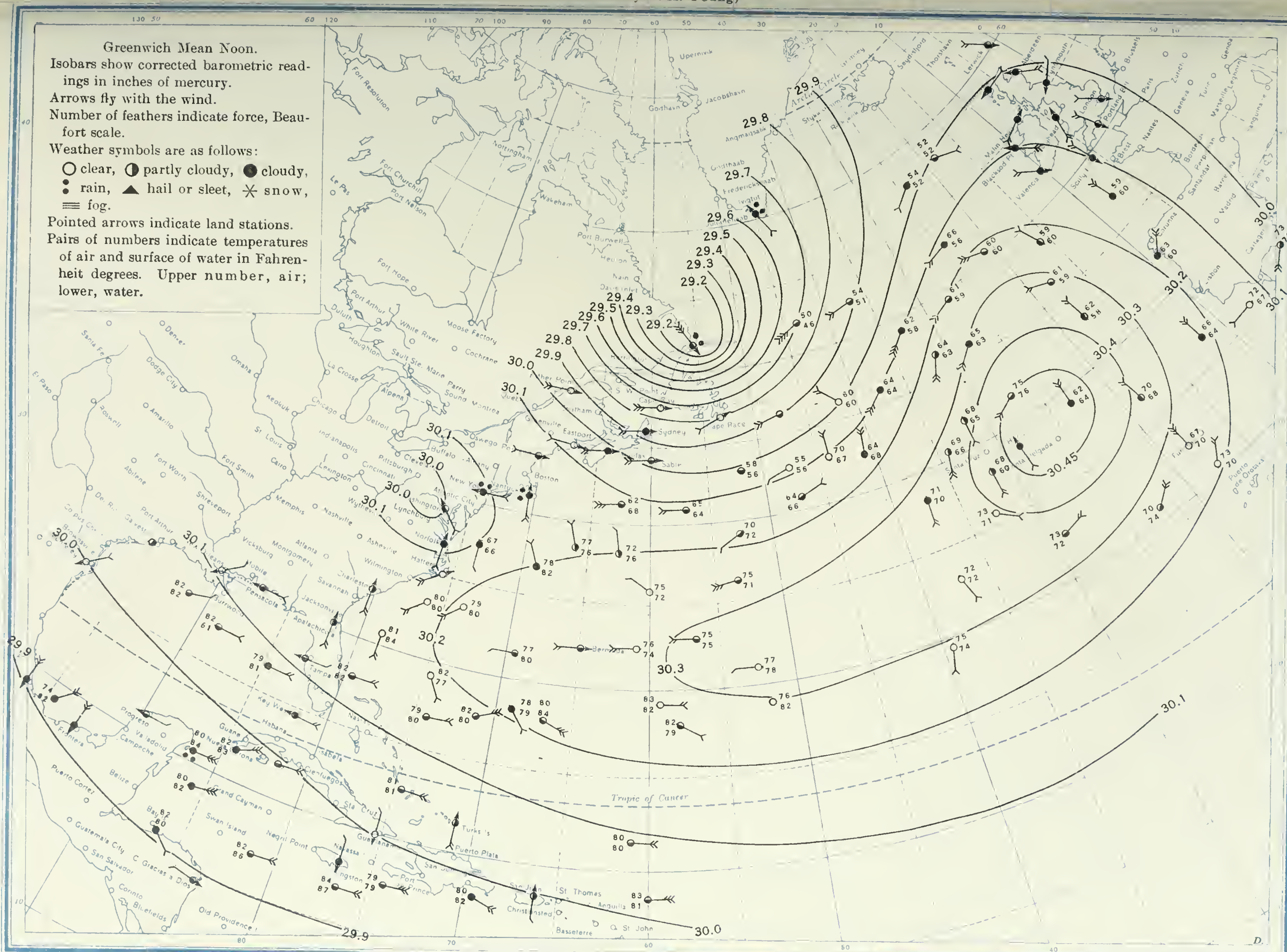
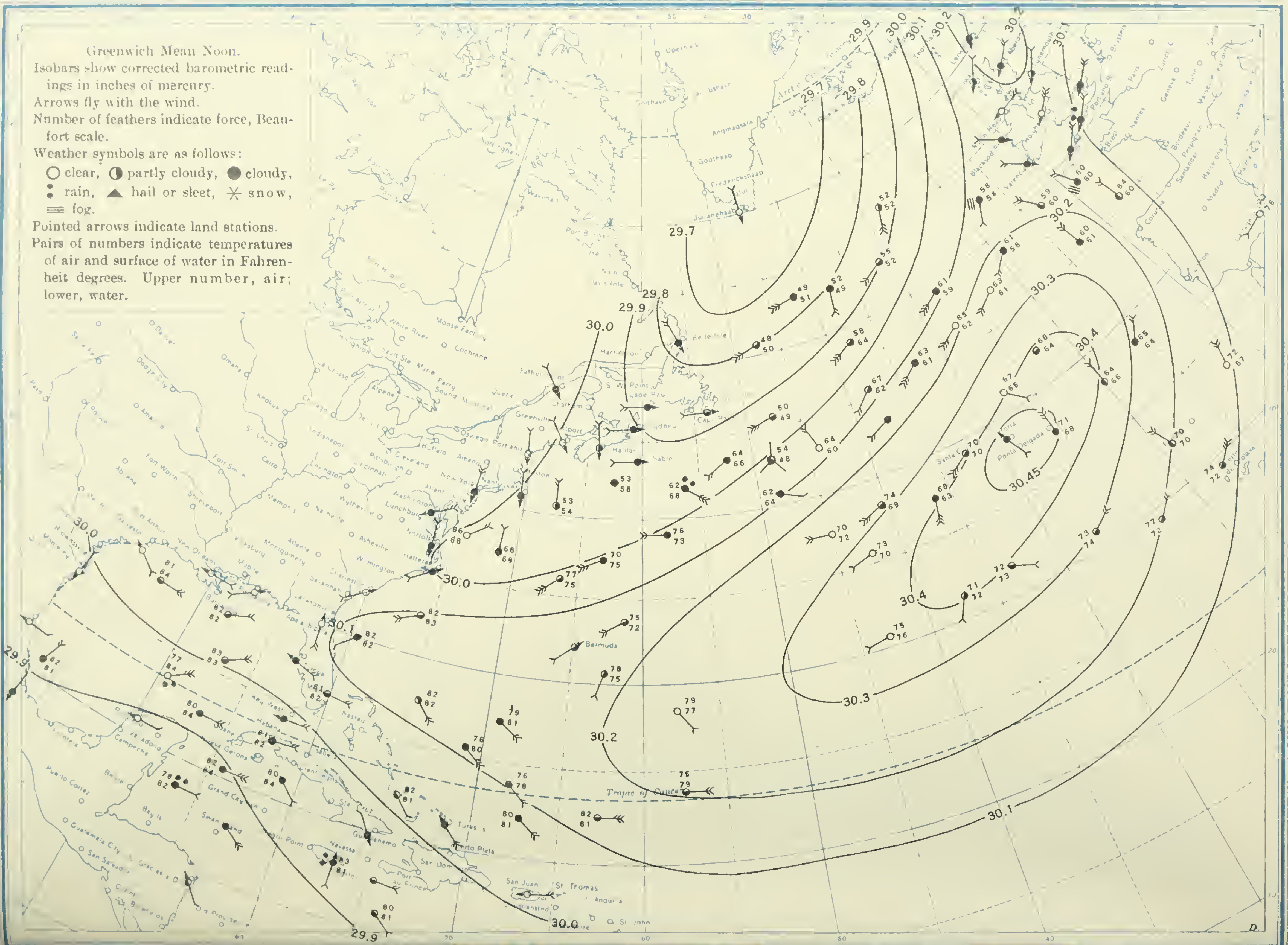
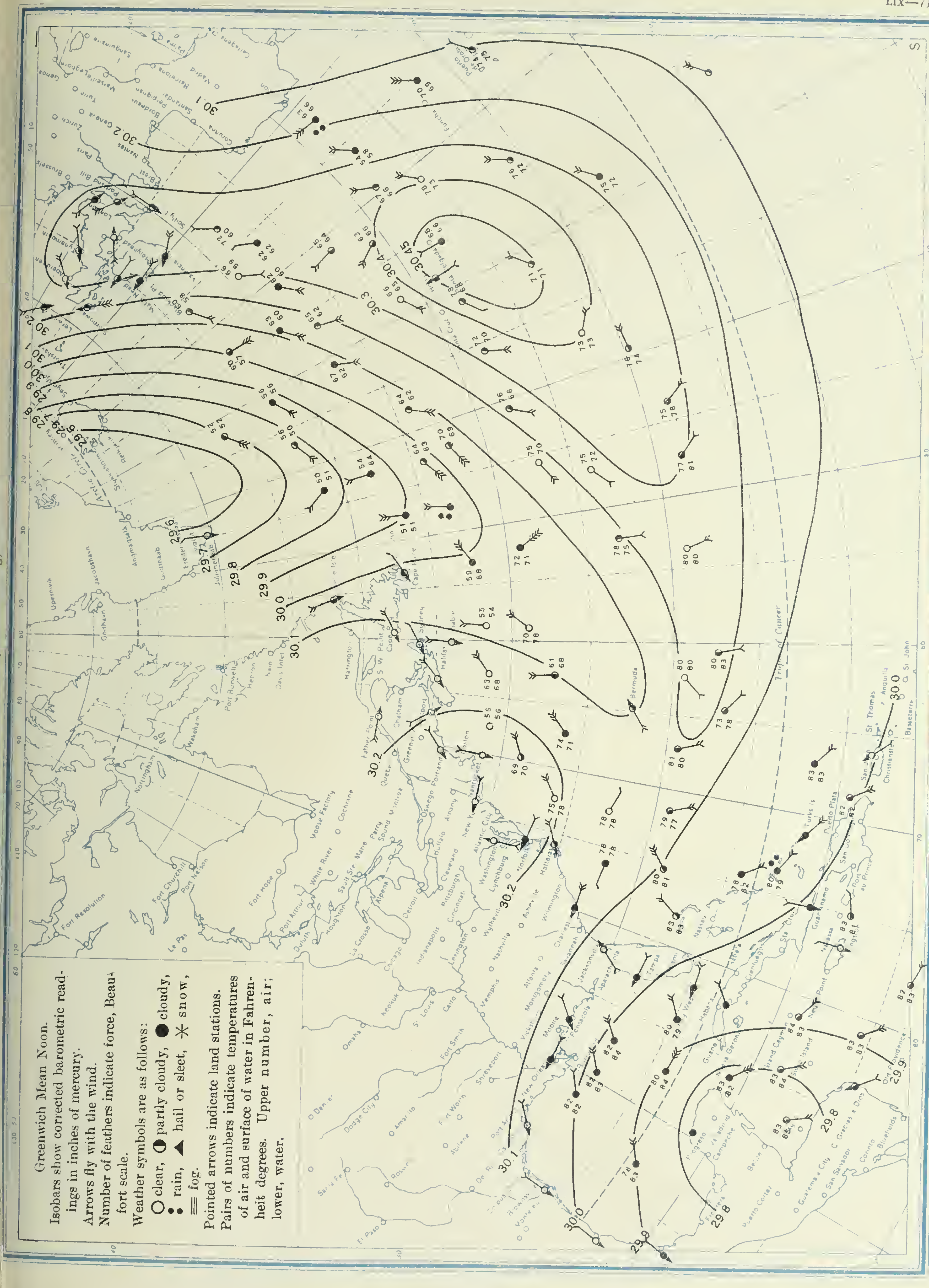
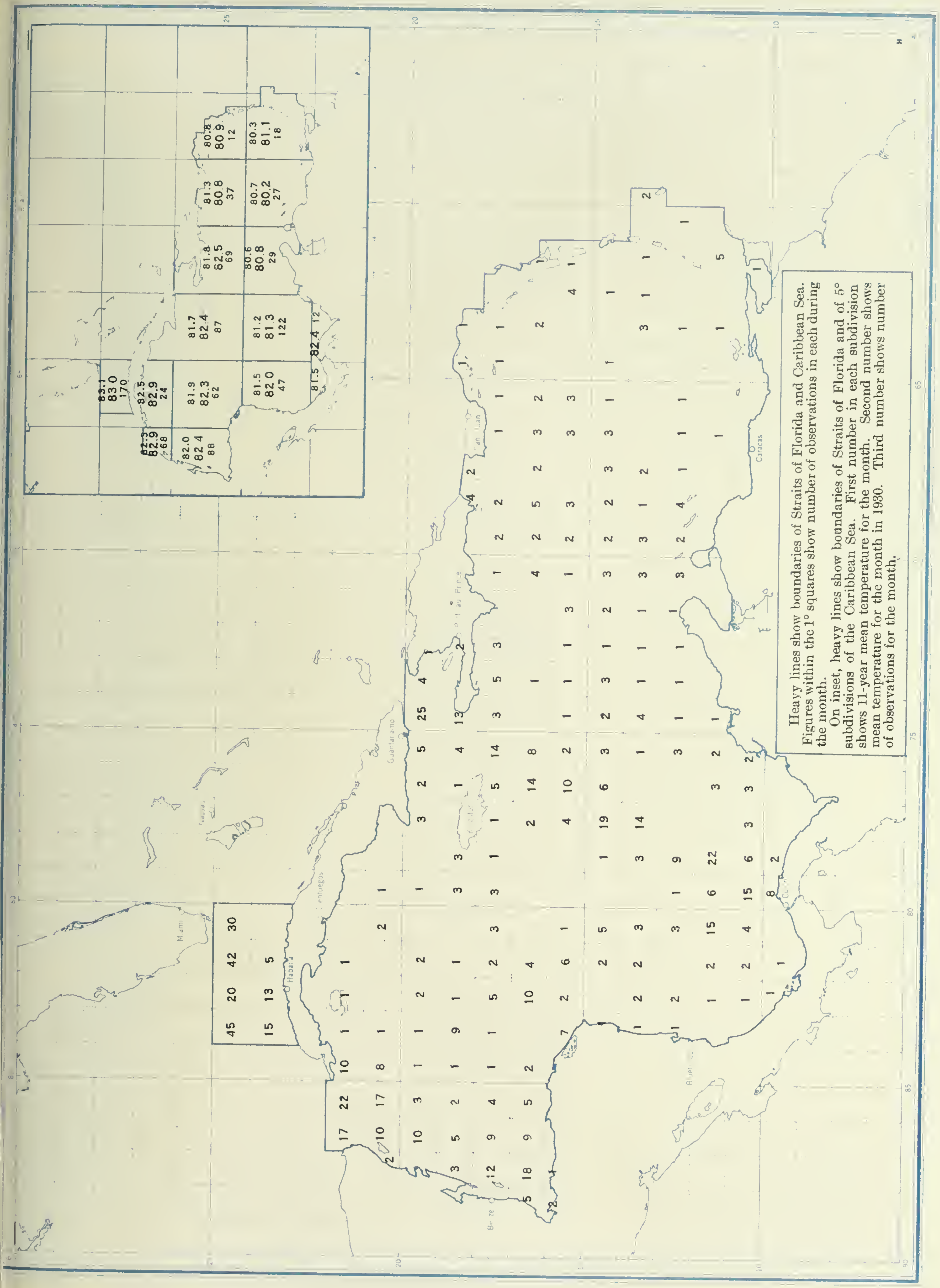


Chart IX. Weather Map of North Atlantic Ocean, June 24, 1931

(Plotted by F. A. Young)




Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: O clear, partly cloudy, cloudy, rain, hail or sleet, snow, fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.



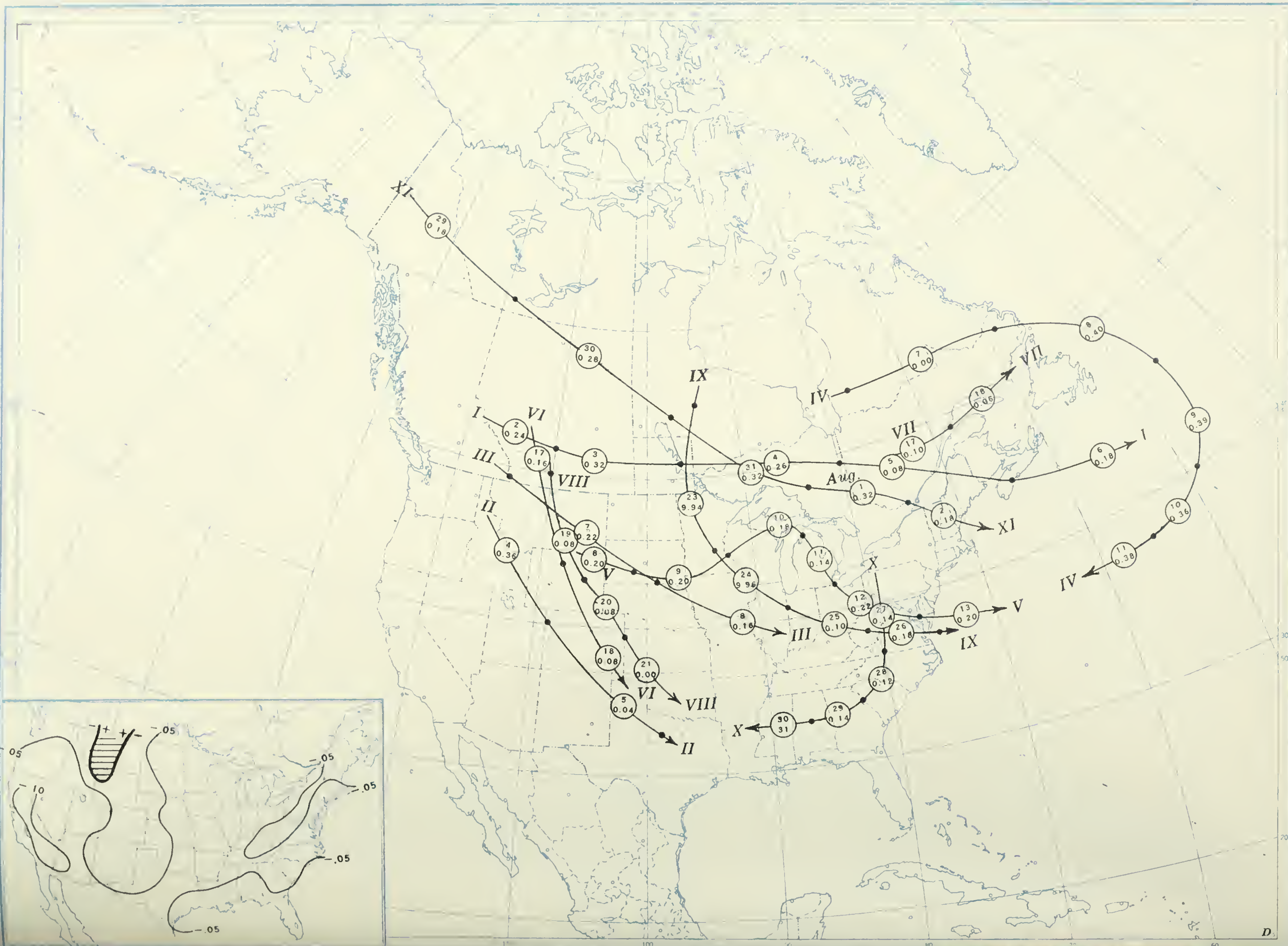
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

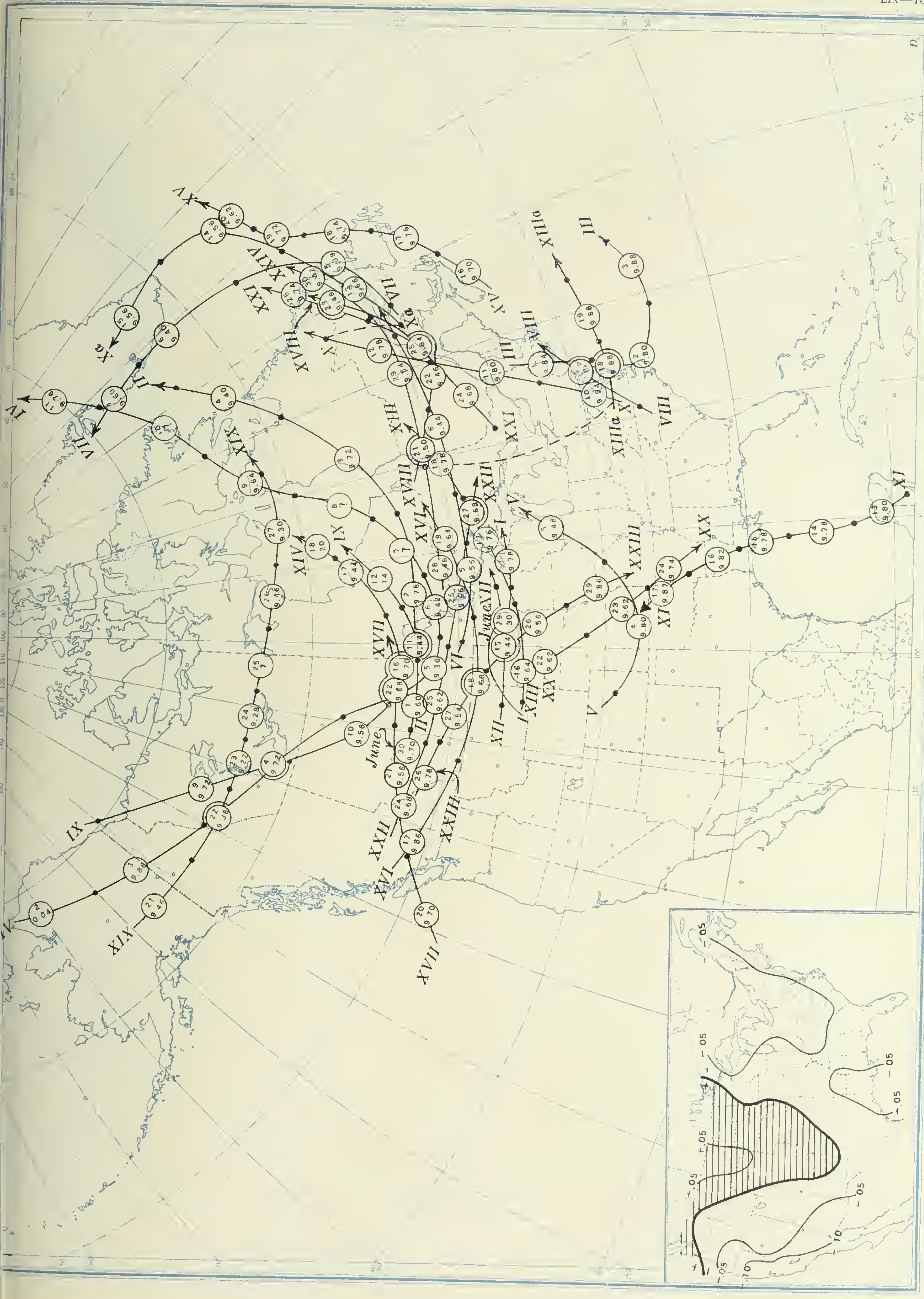
On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
+2°
+4°
+6°
−2°
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, July, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)





Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, July, 1931

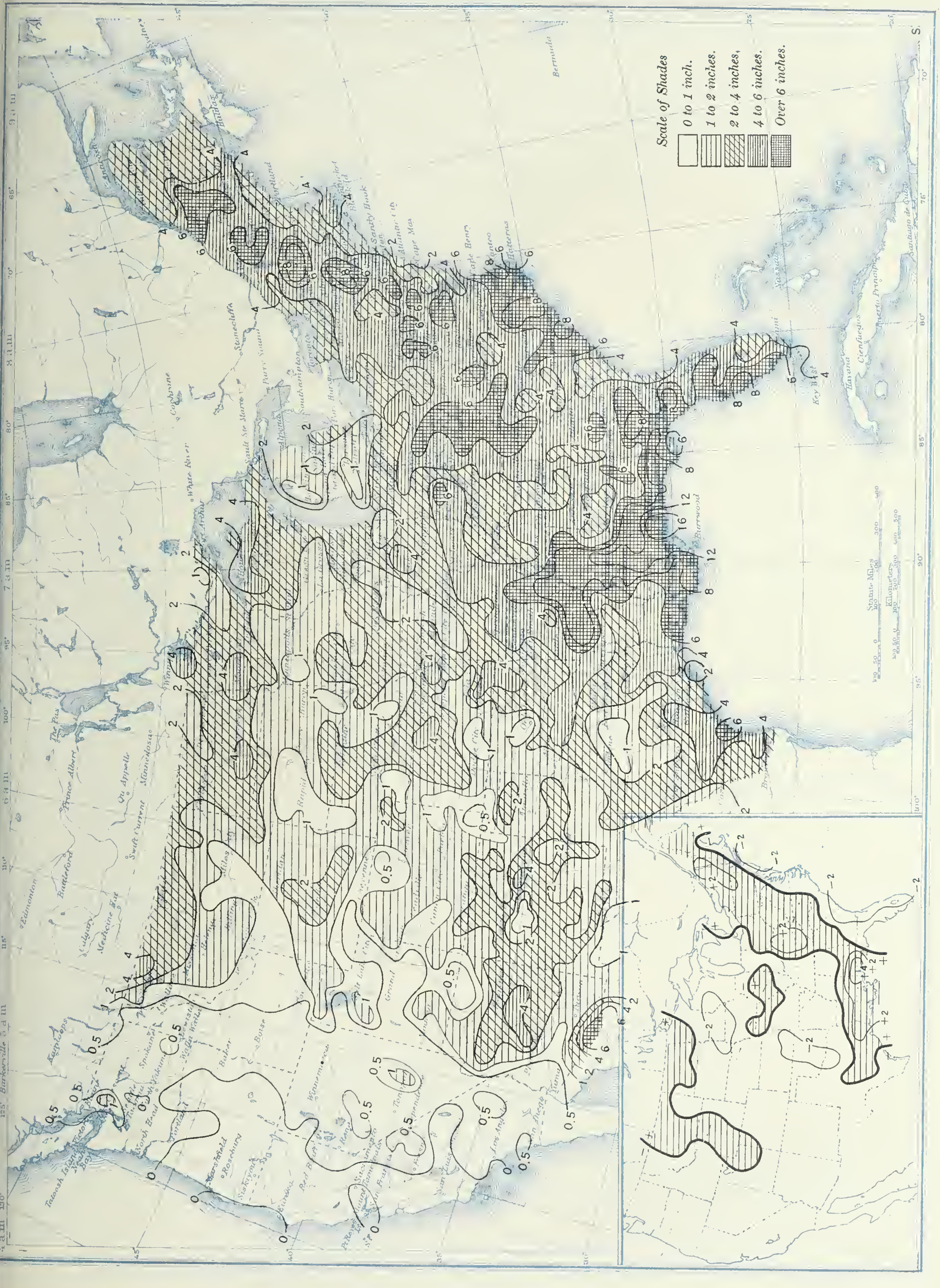
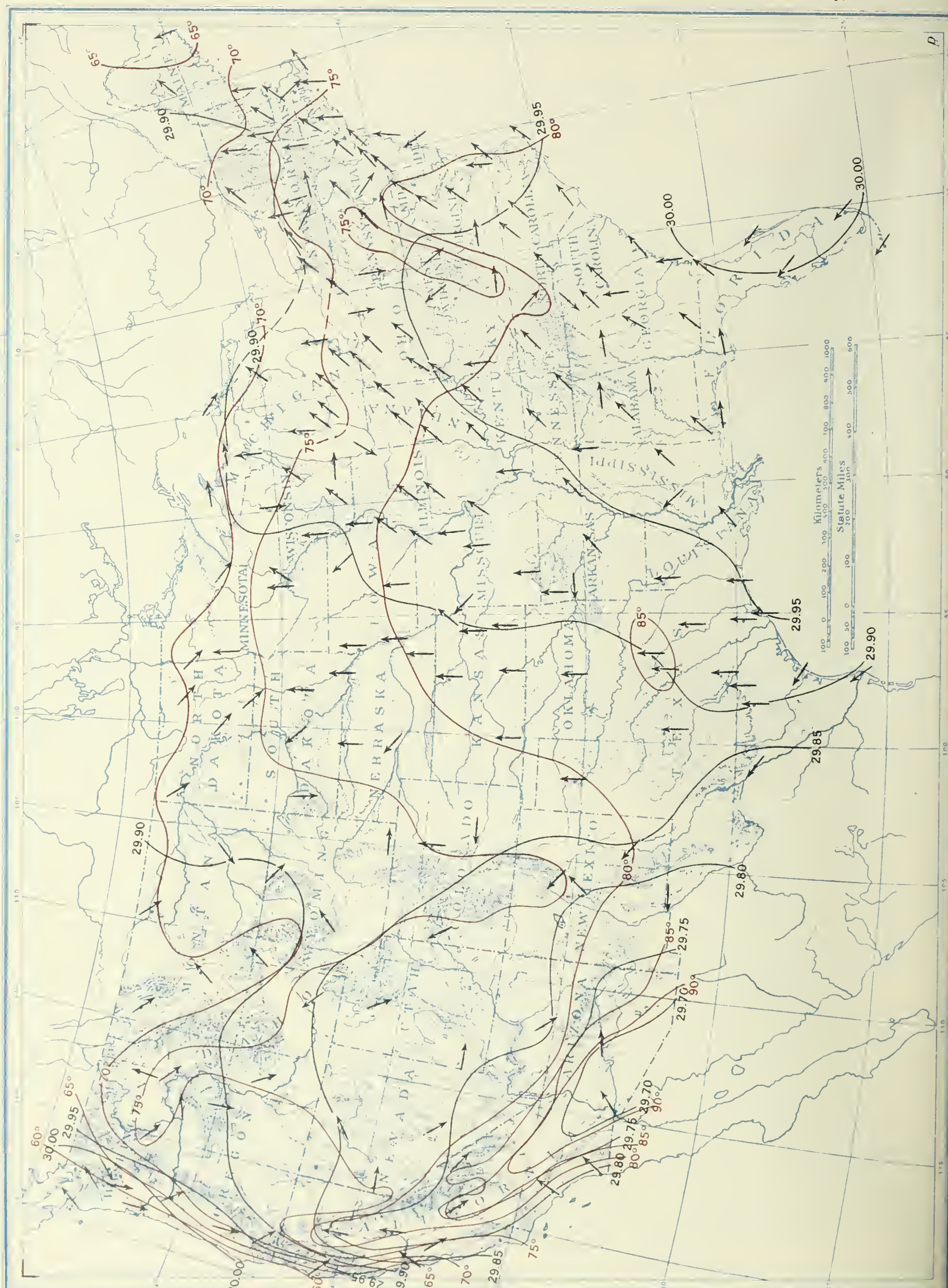

Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, July, 1931



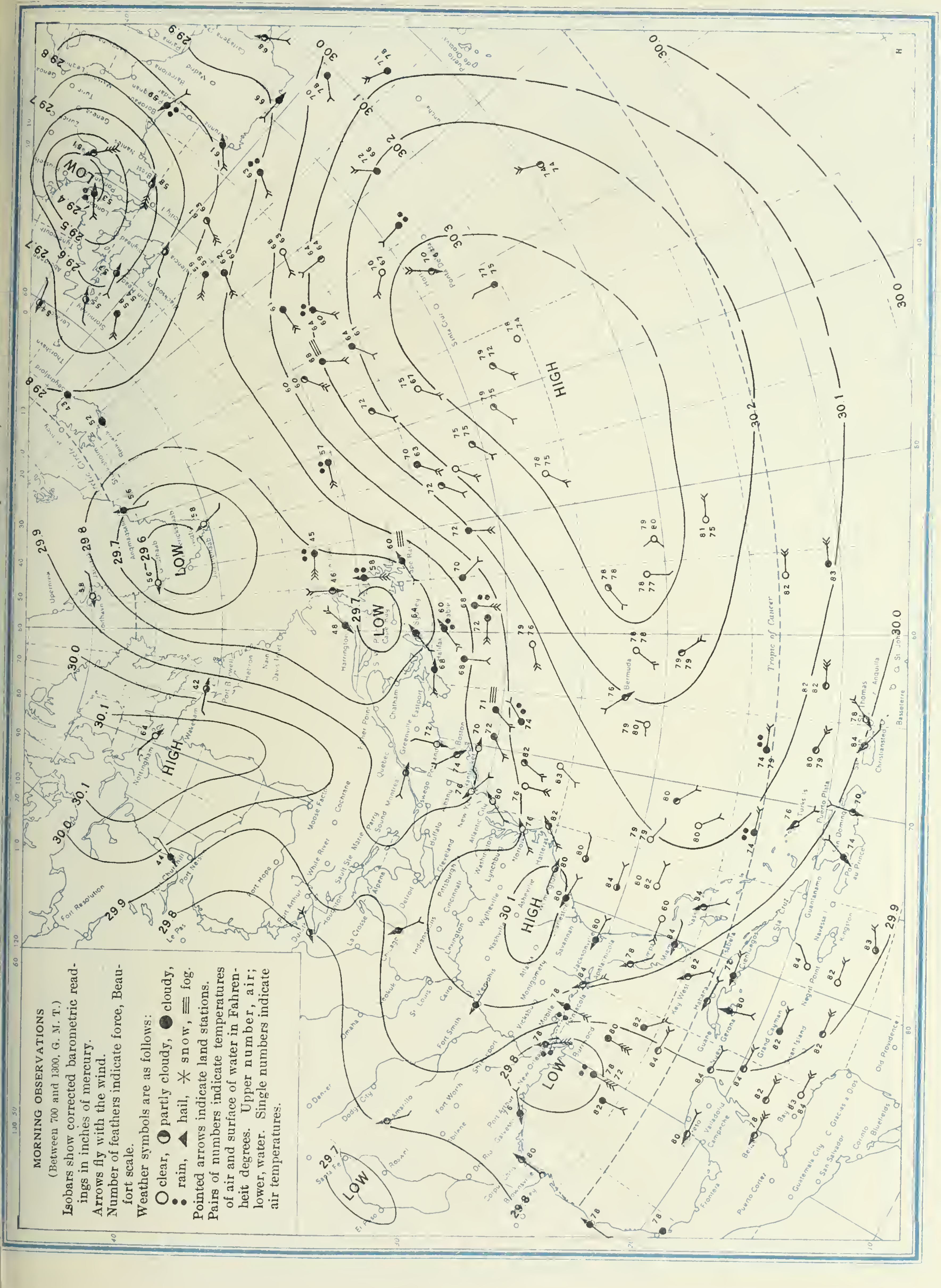

MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◐ partly cloudy, ● cloudy, ⁚ rain, ▲ hail, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.
HIGH
LOW
Tropic of Cancer

Chart IX. Weather Map of North Atlantic Ocean, July 16, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)

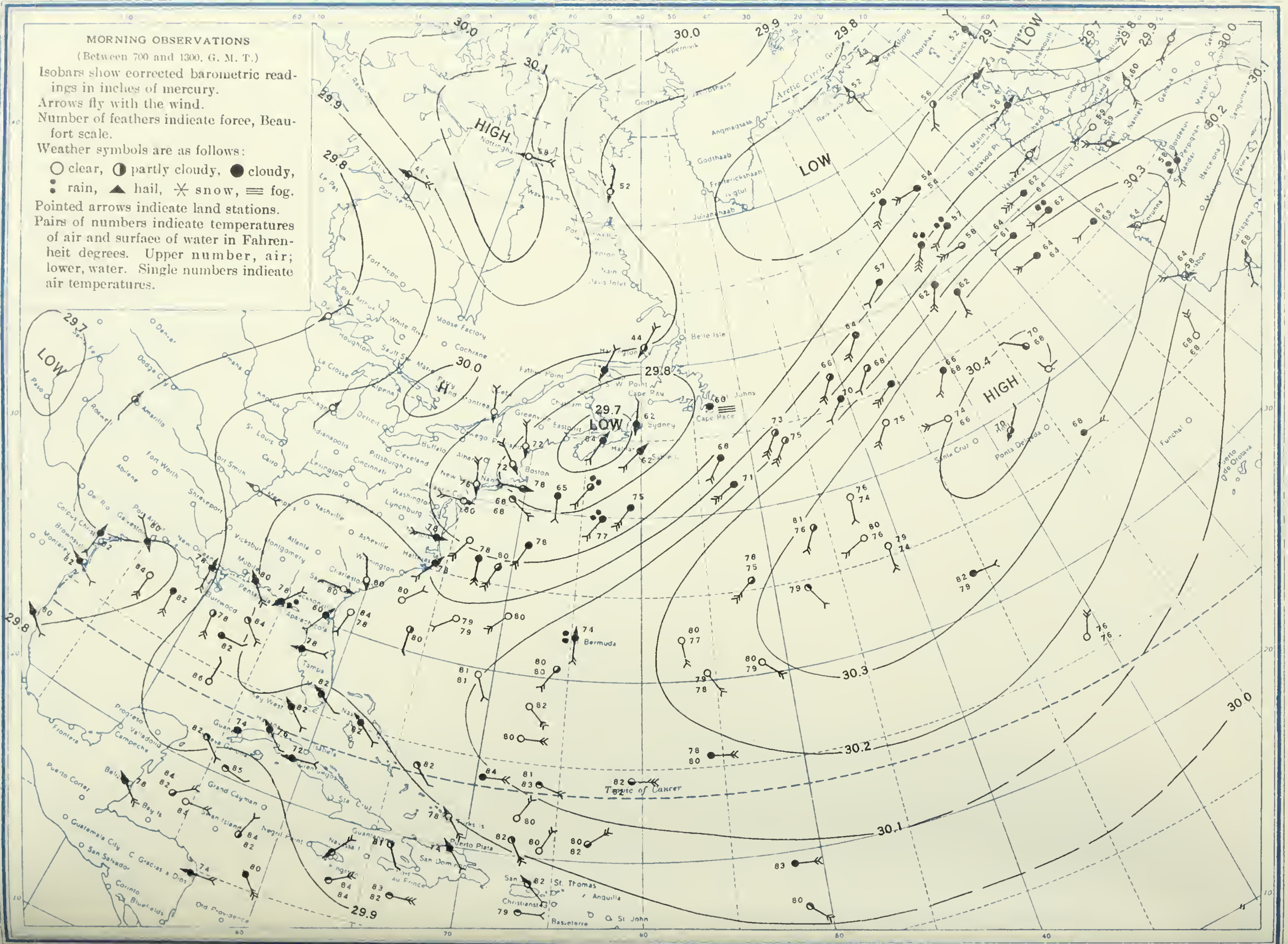


Chart X. Weather Map of North Atlantic O...
(Plotted from the Weather Bureau Northern Hemisphere Chart)

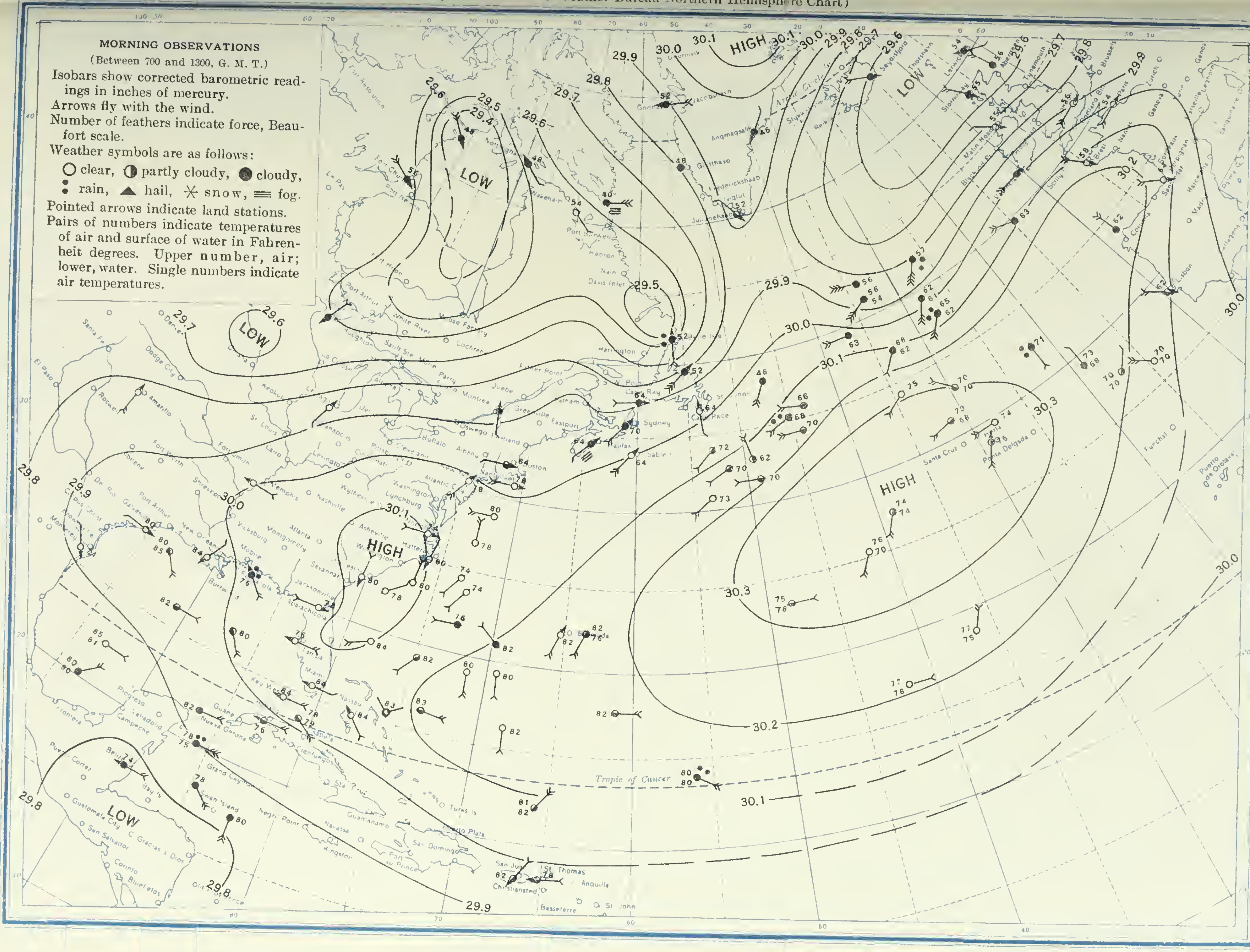
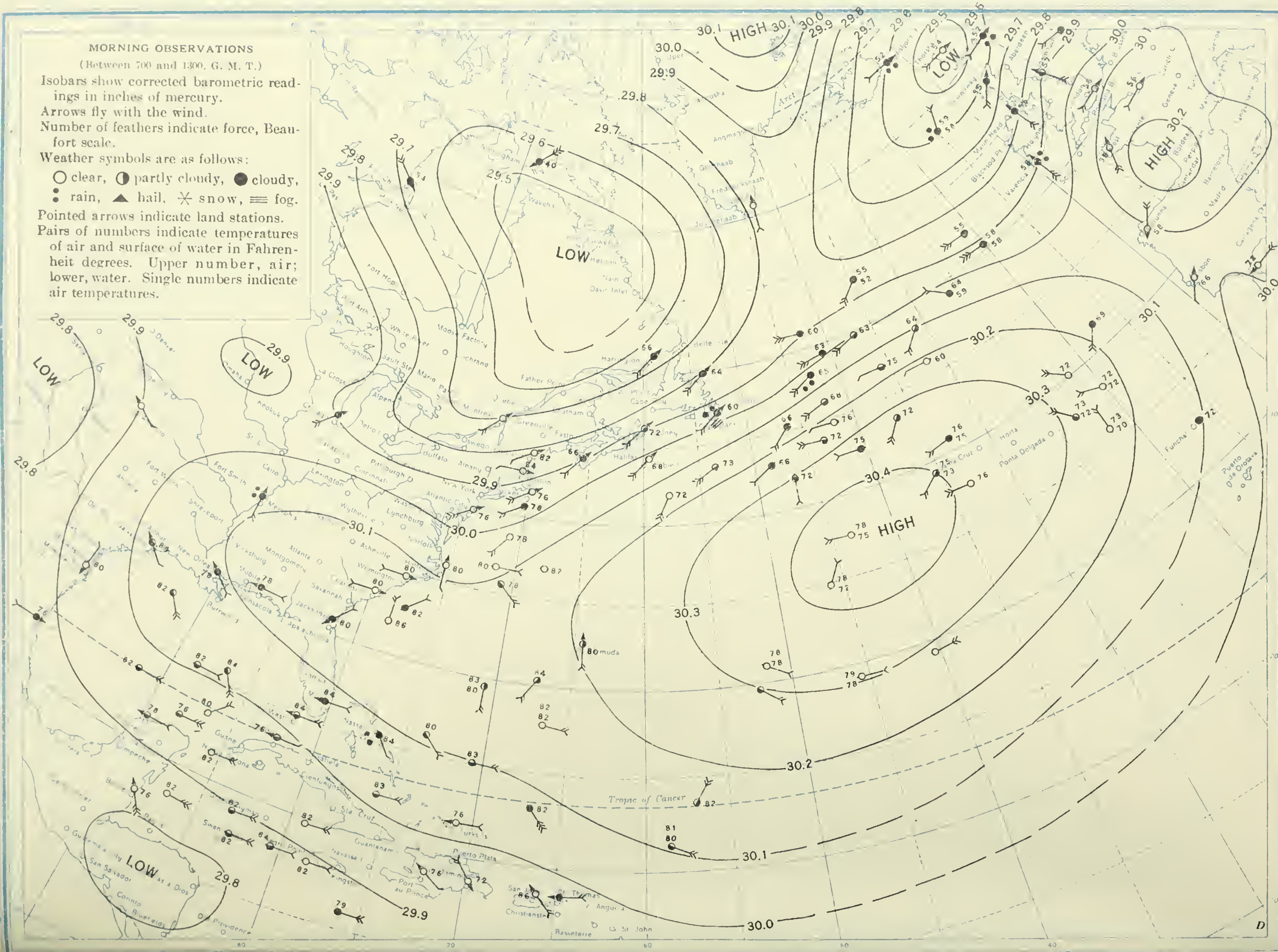
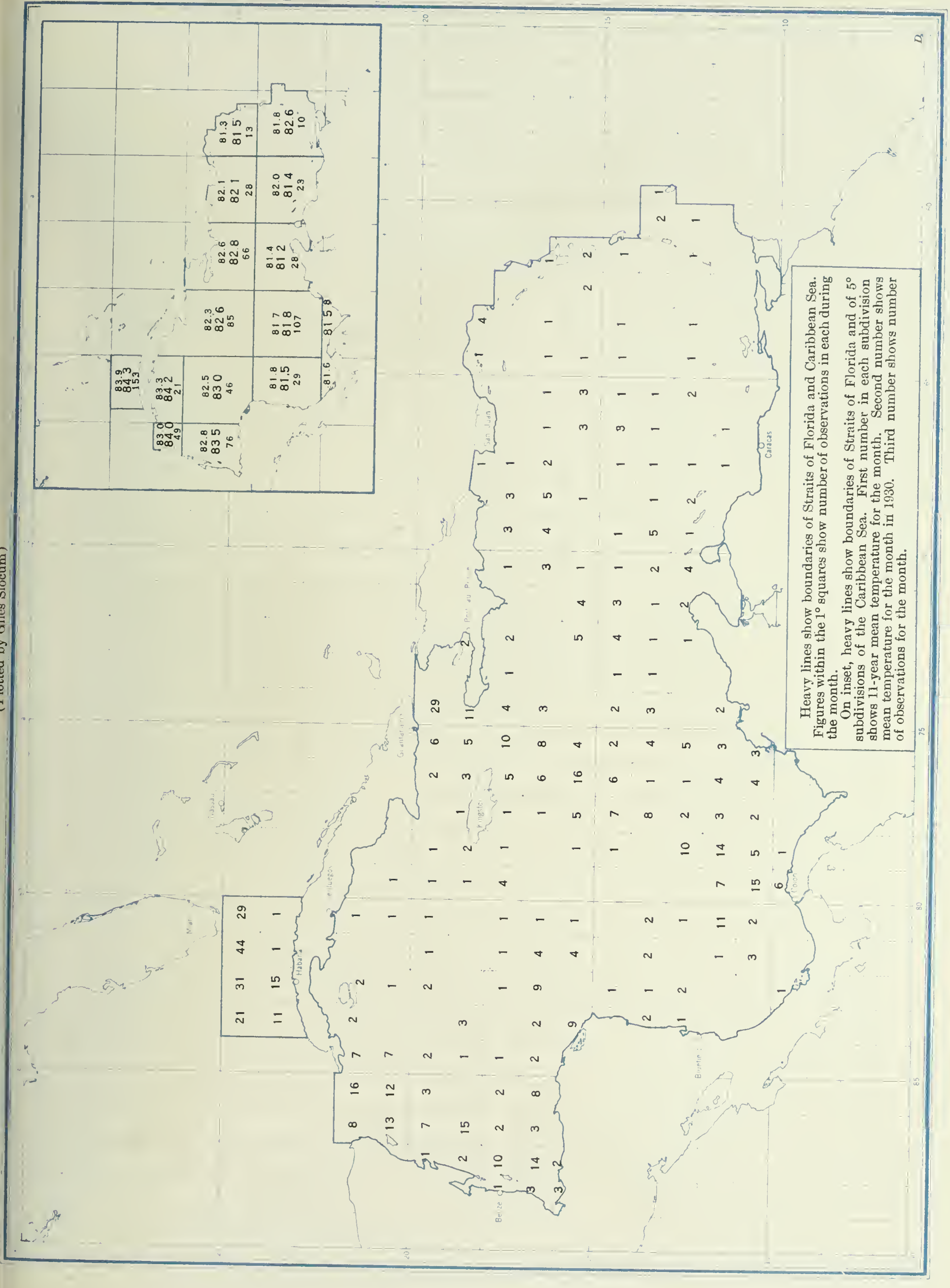


Chart XI. Weather Map of North Atlantic Ocean, July 29, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

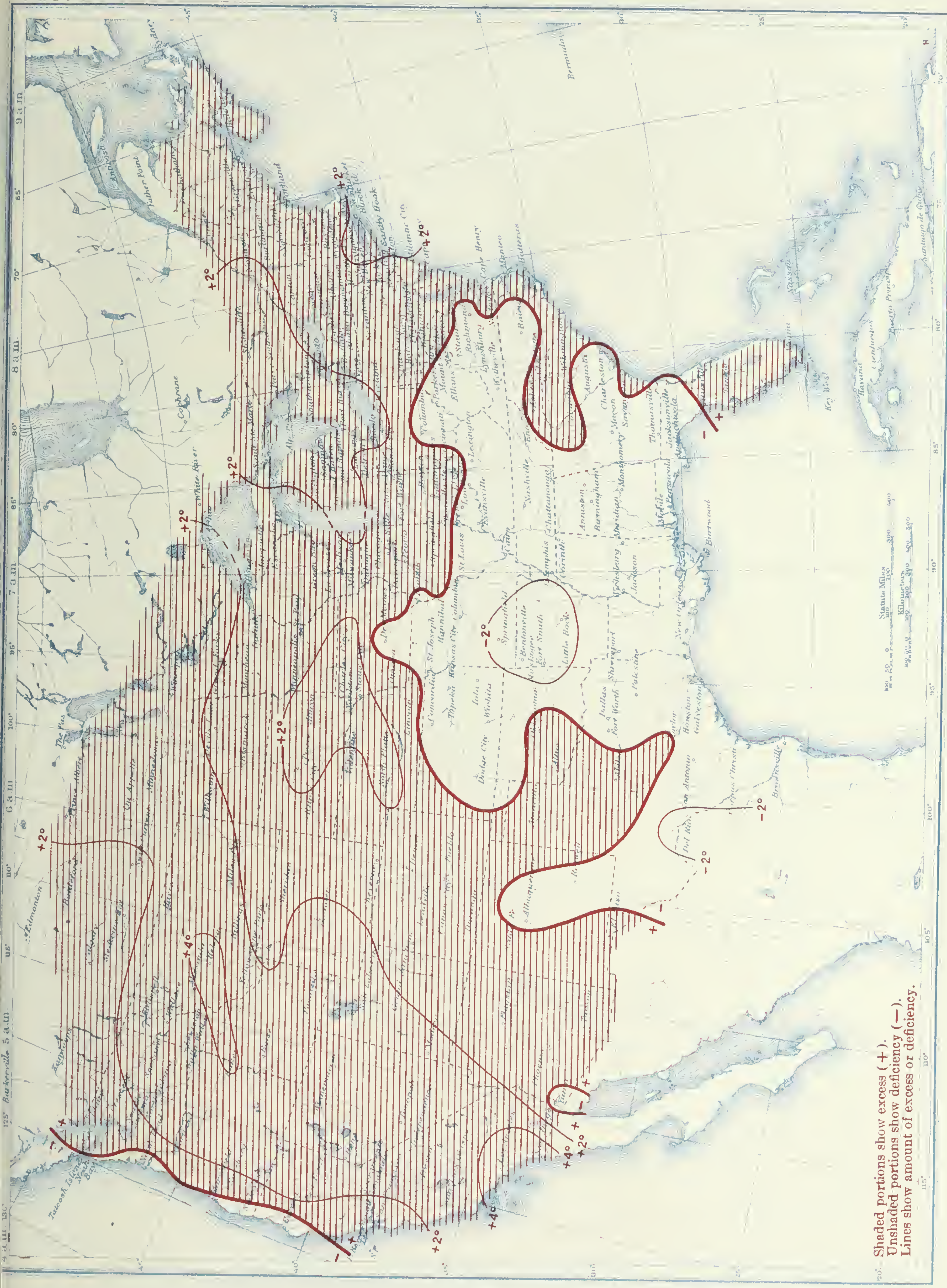
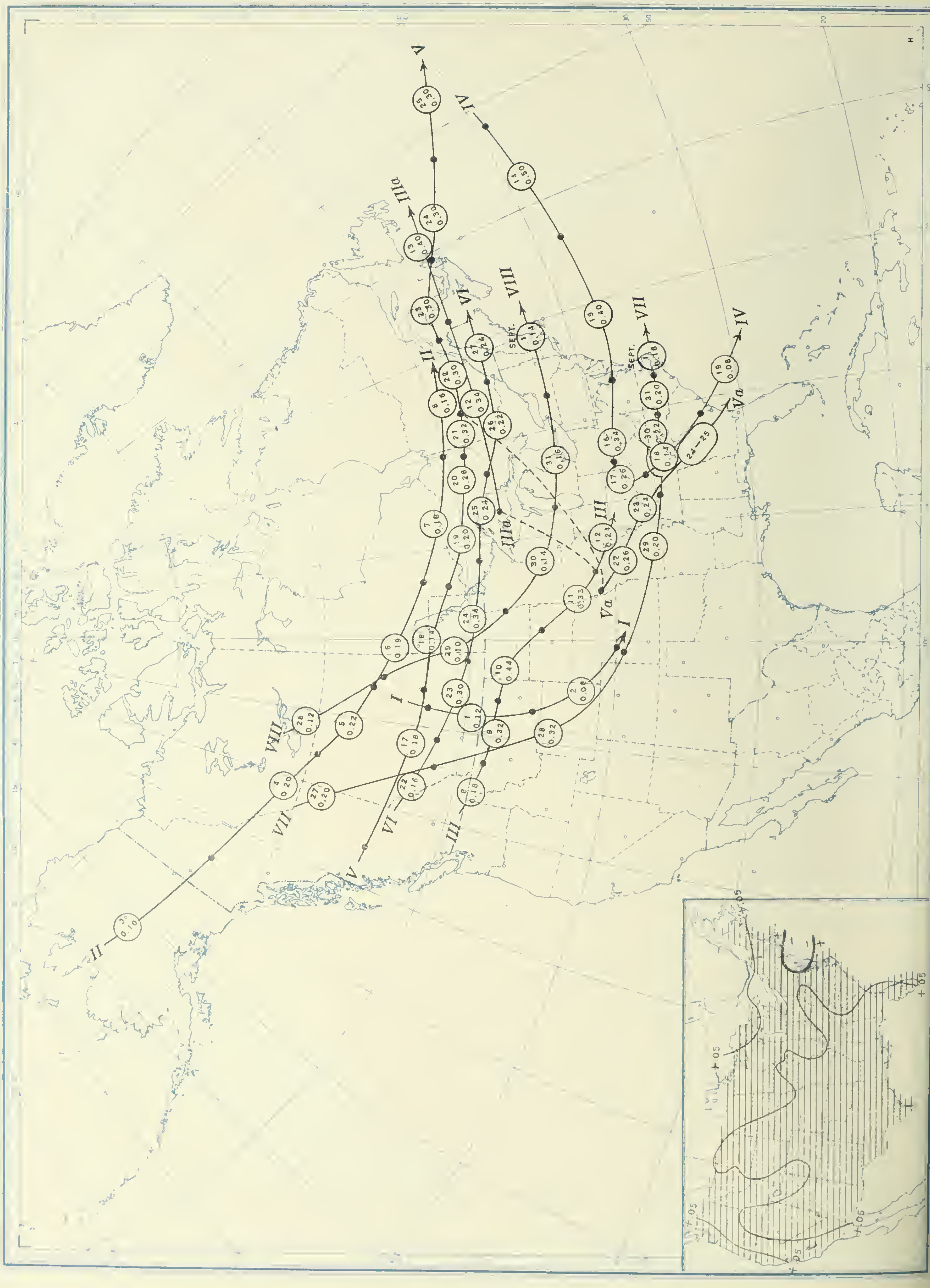
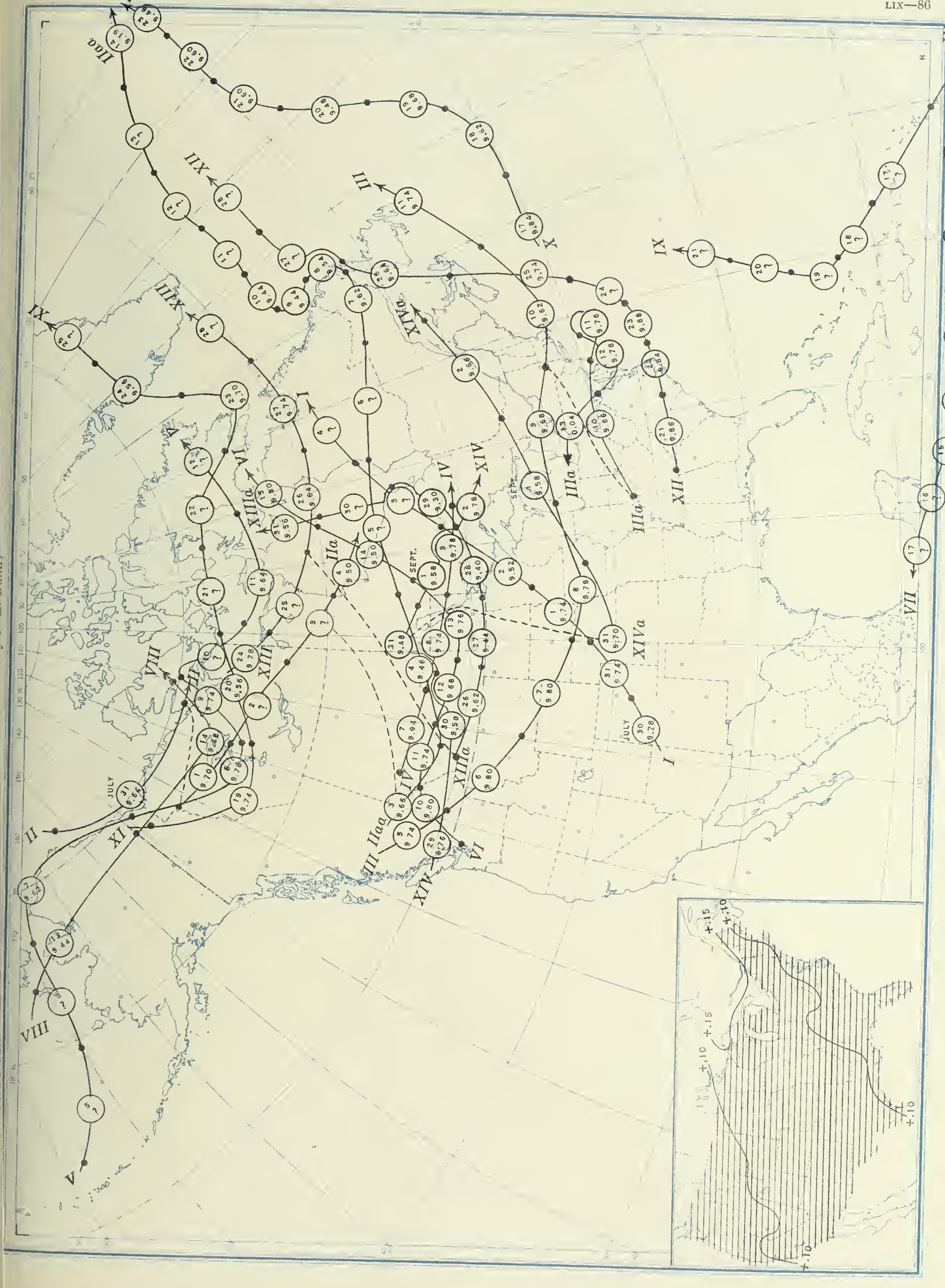

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, August, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

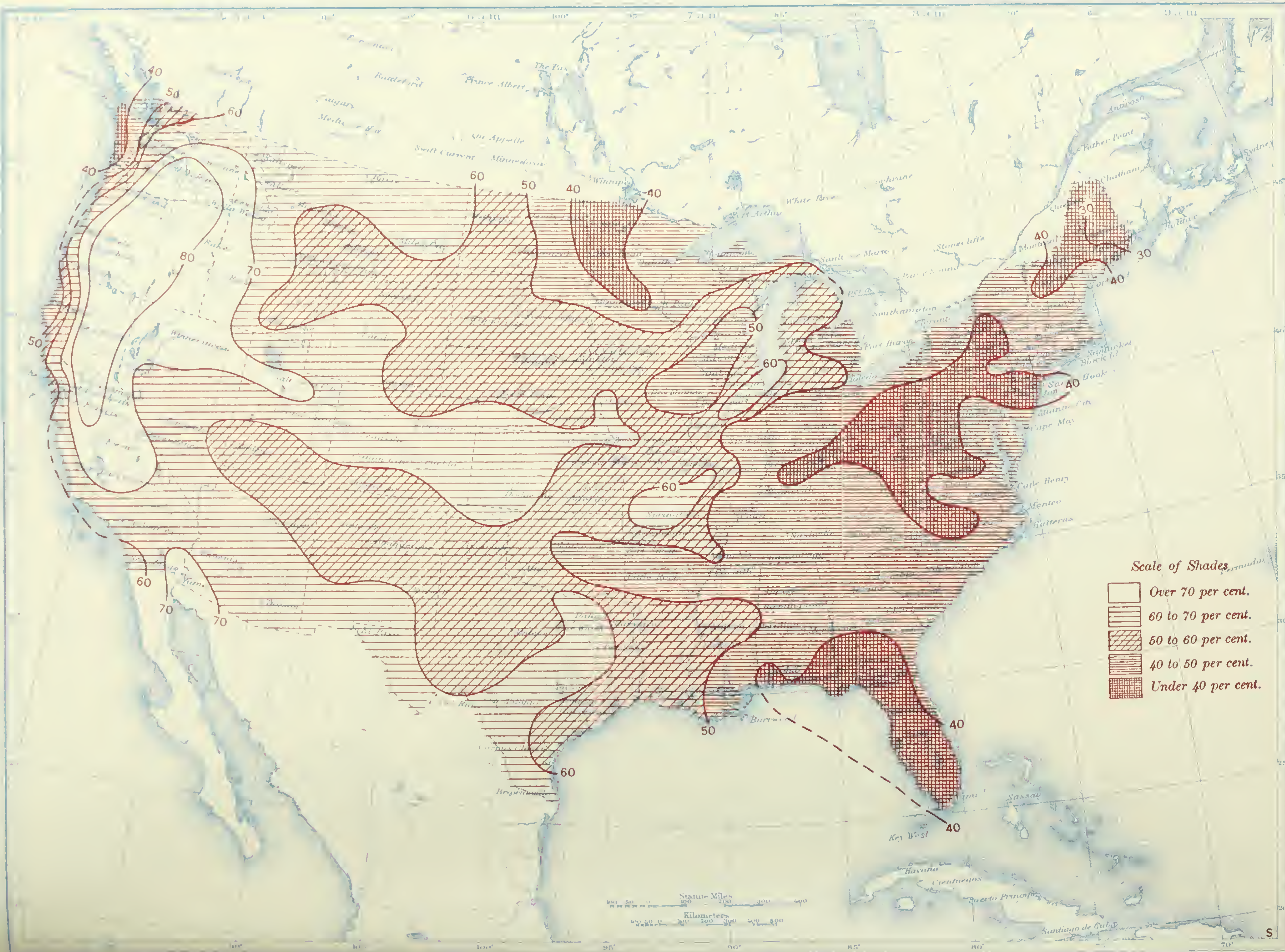
(Plotted by G. E. Dunn)





Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, August, 1931



Total Precipitation, Inches, August, 1931. (Inset) Departure of Precipitation

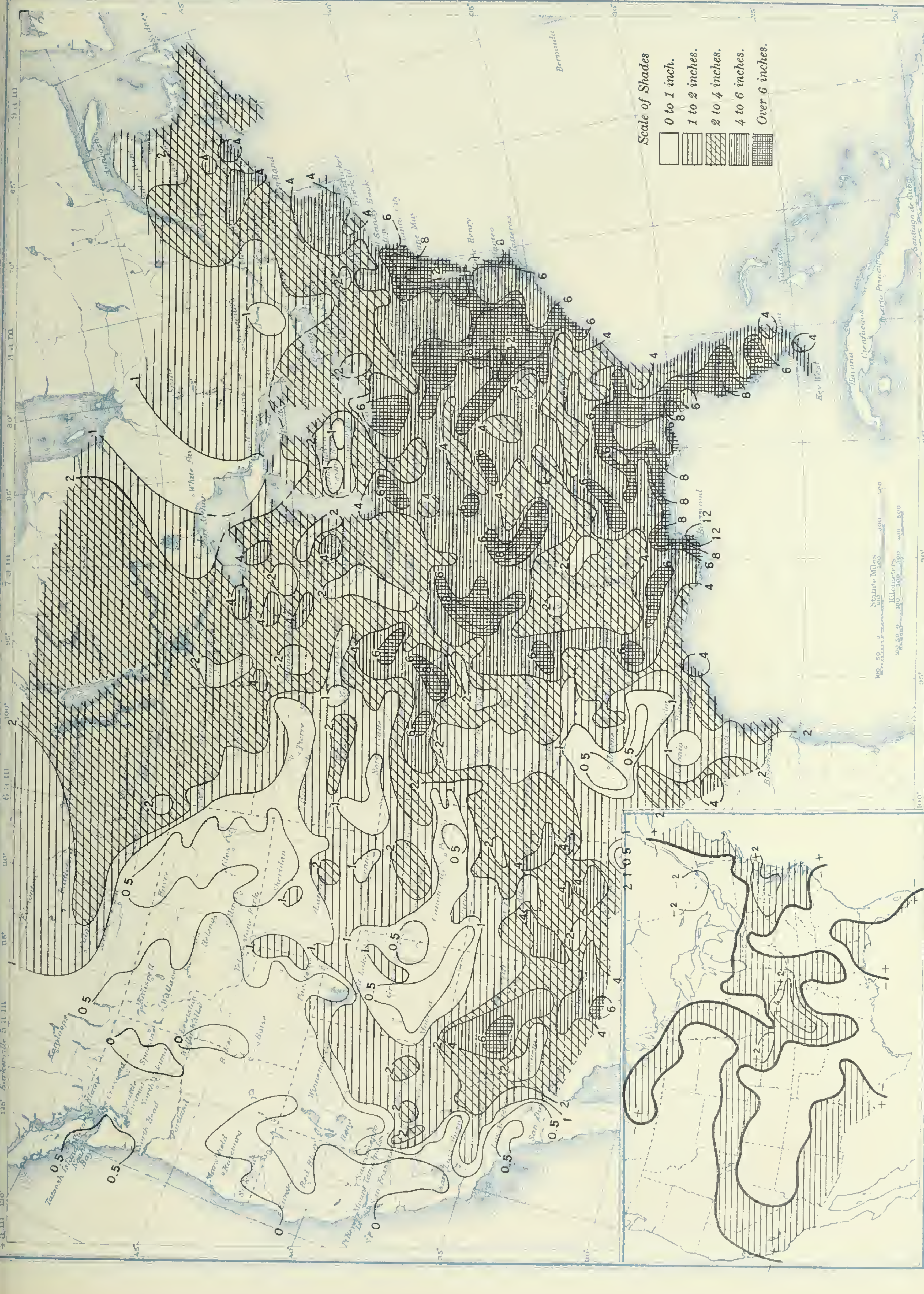
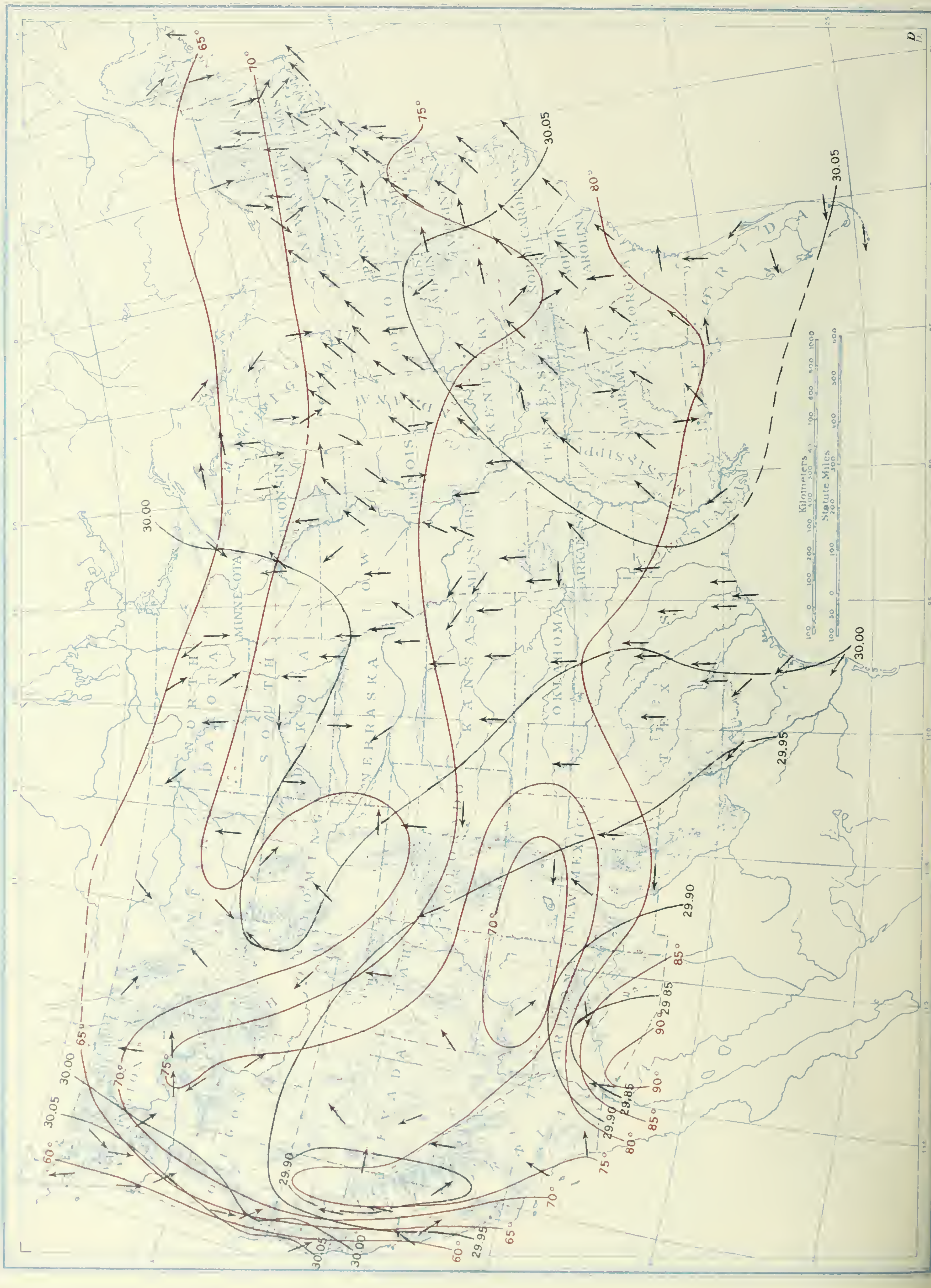
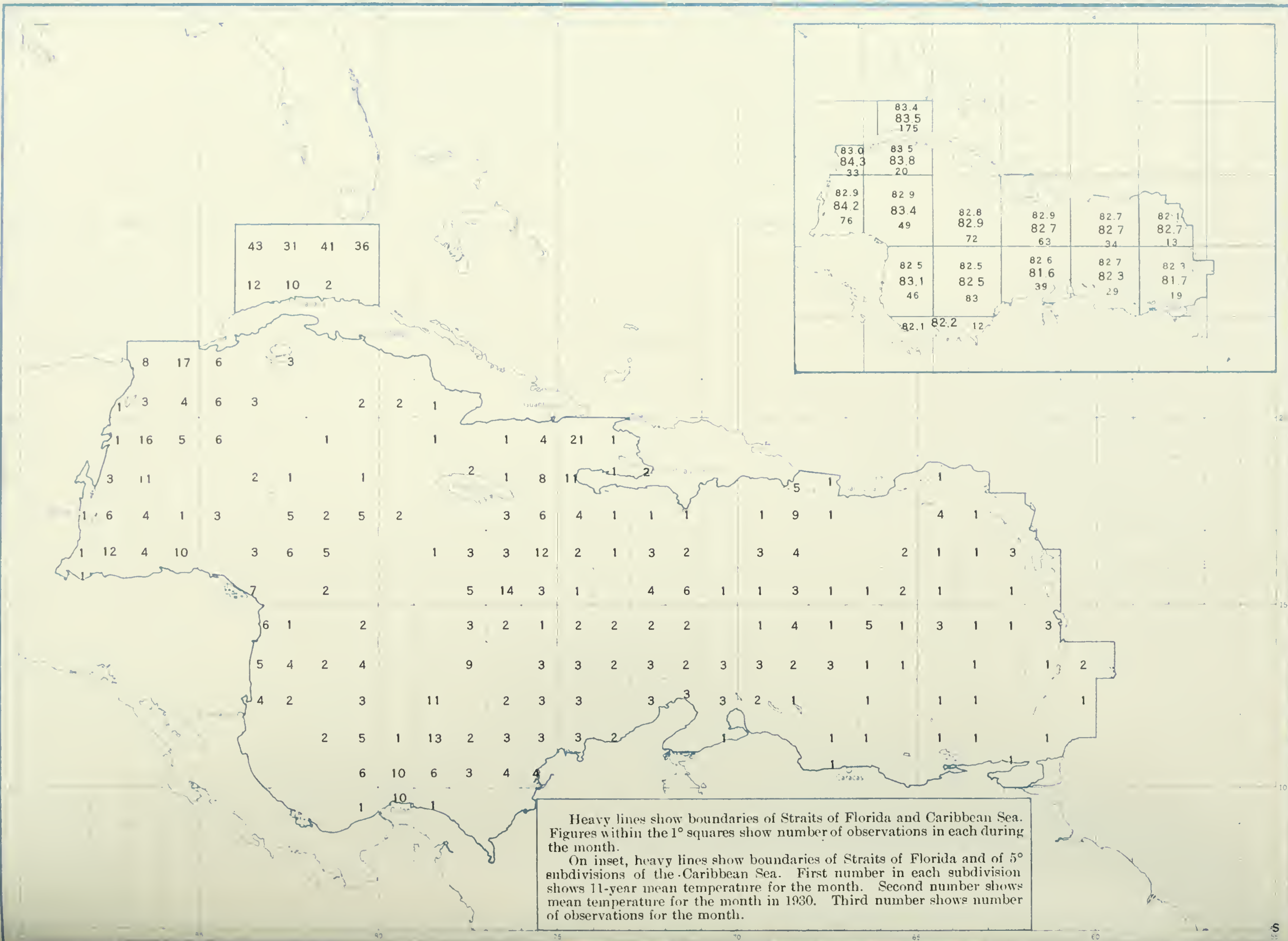


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, August, 1931



Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, September, 1931

(Plotted by Giles Slocum)



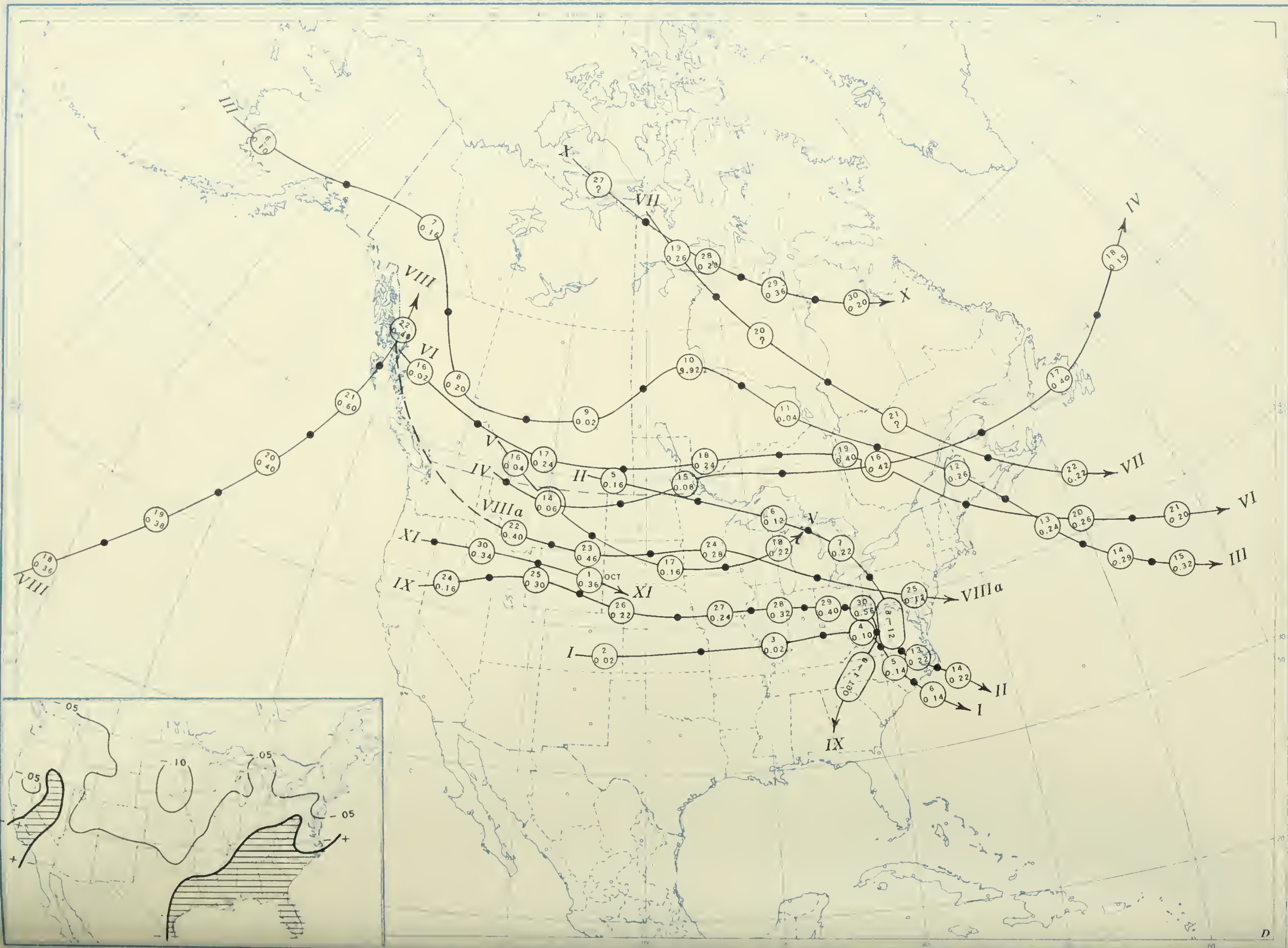
Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

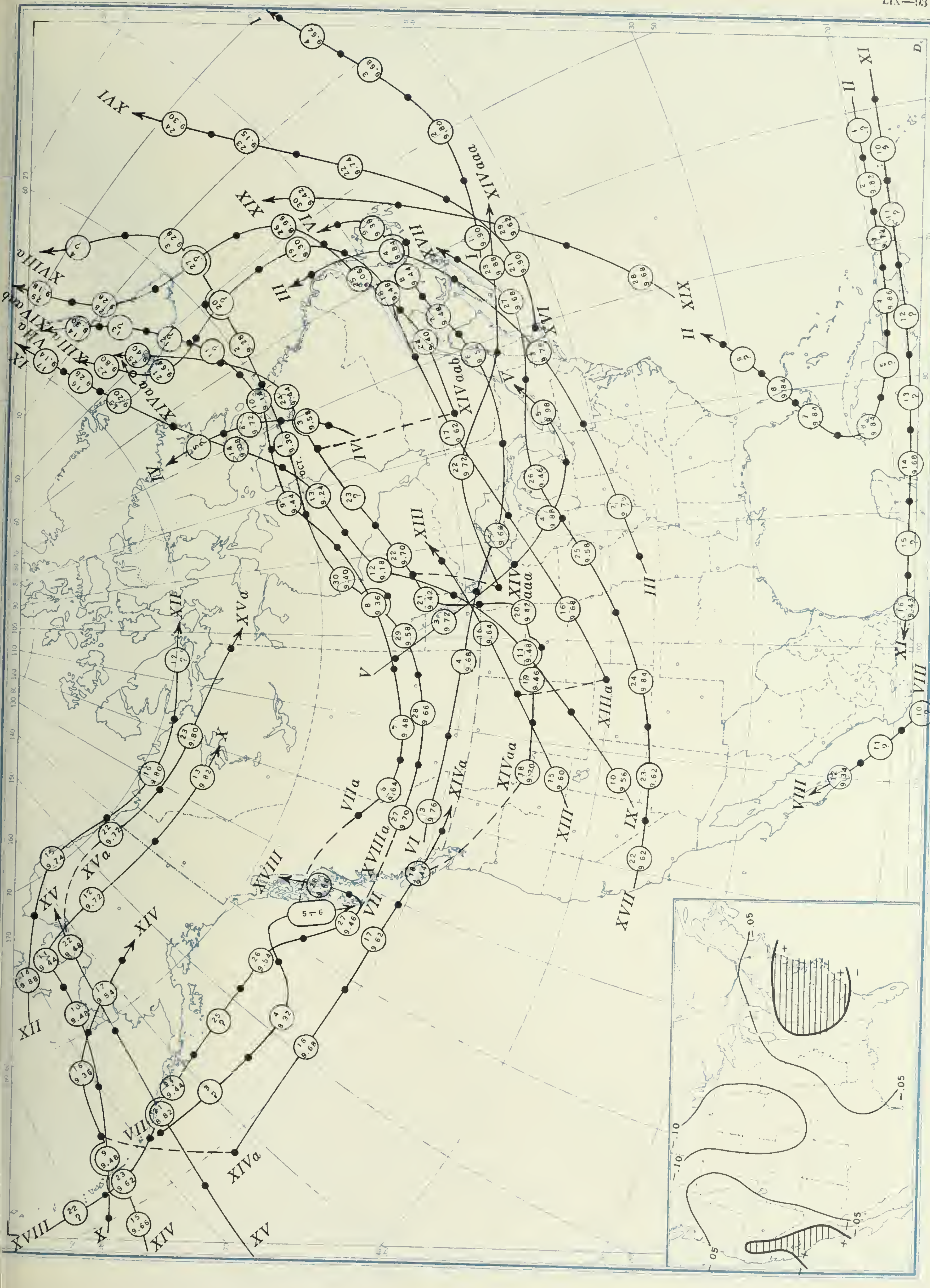
On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.


Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, September, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)





Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, September, 1931

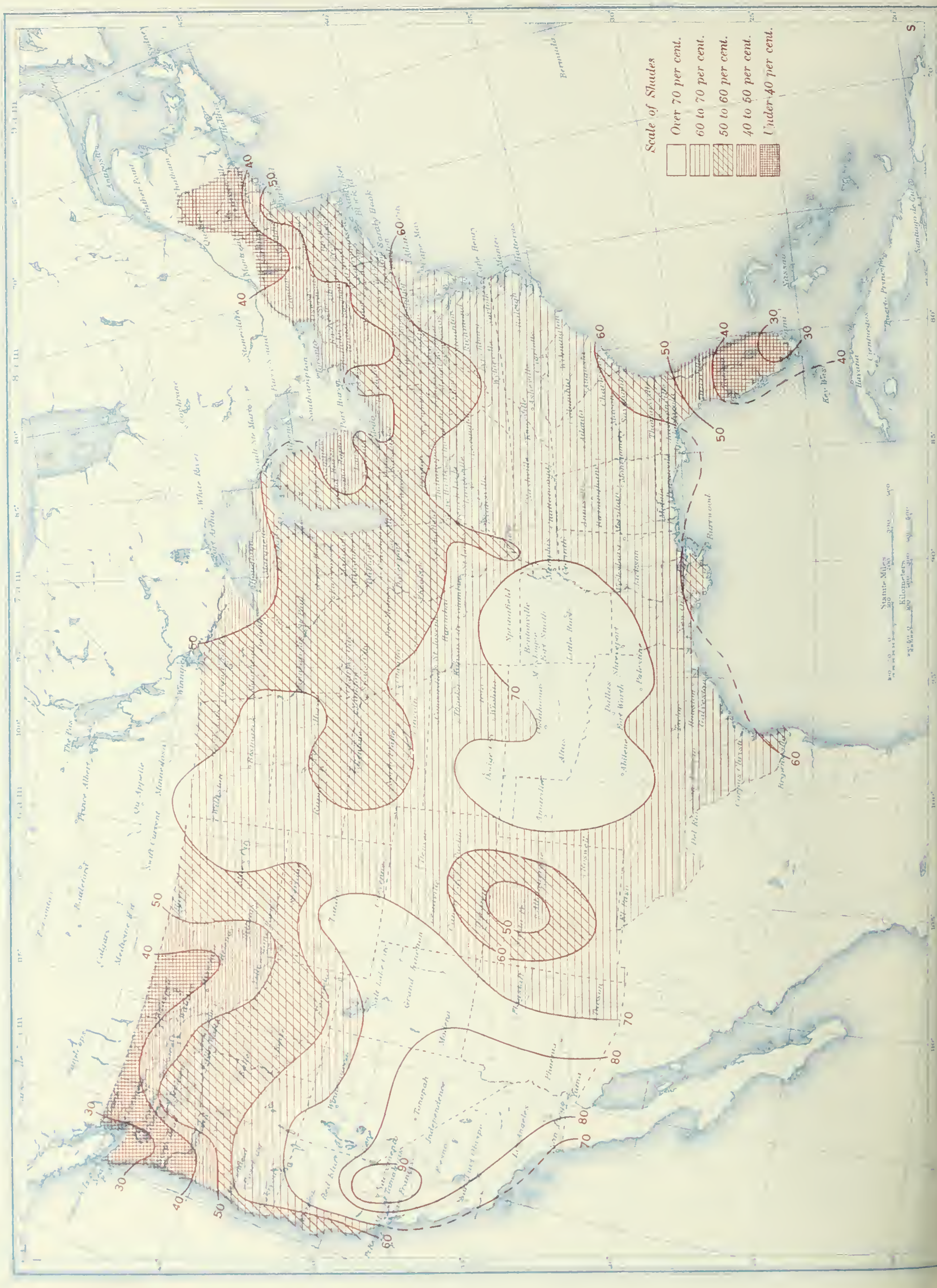


Chart V. Total Precipitation, Inches, September, 1931. (Inset) Departure of Precipitation

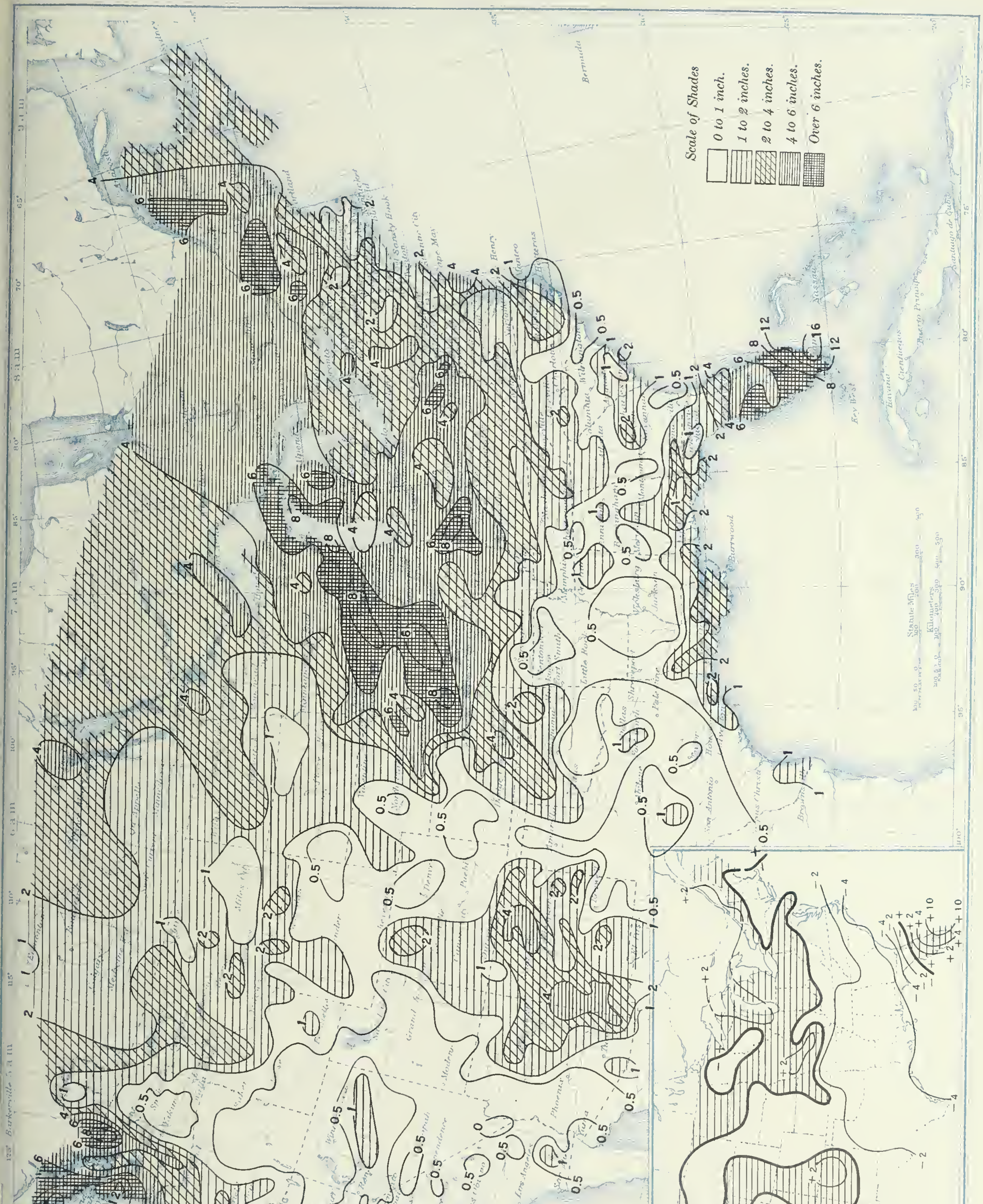
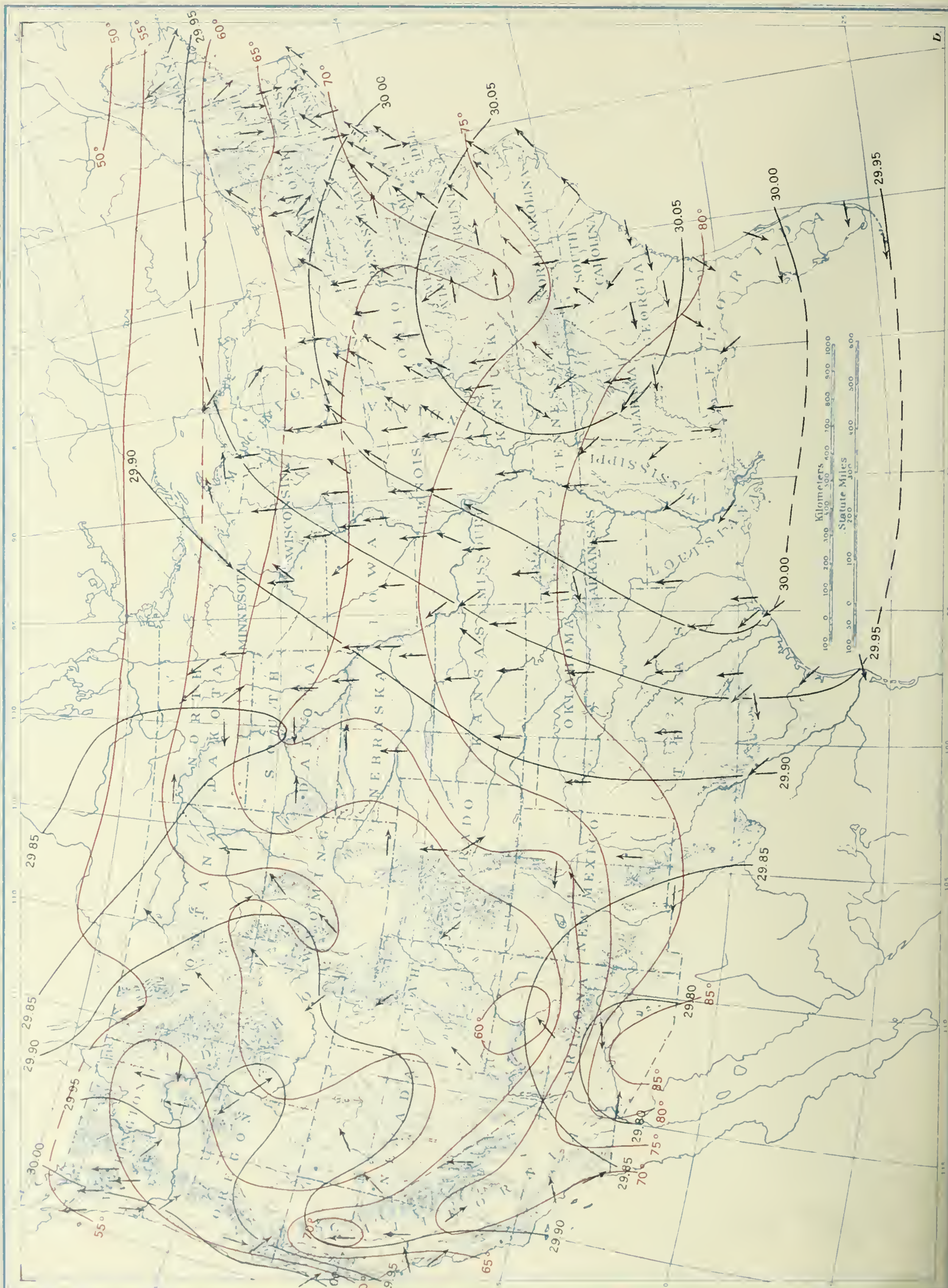


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, September, 1931



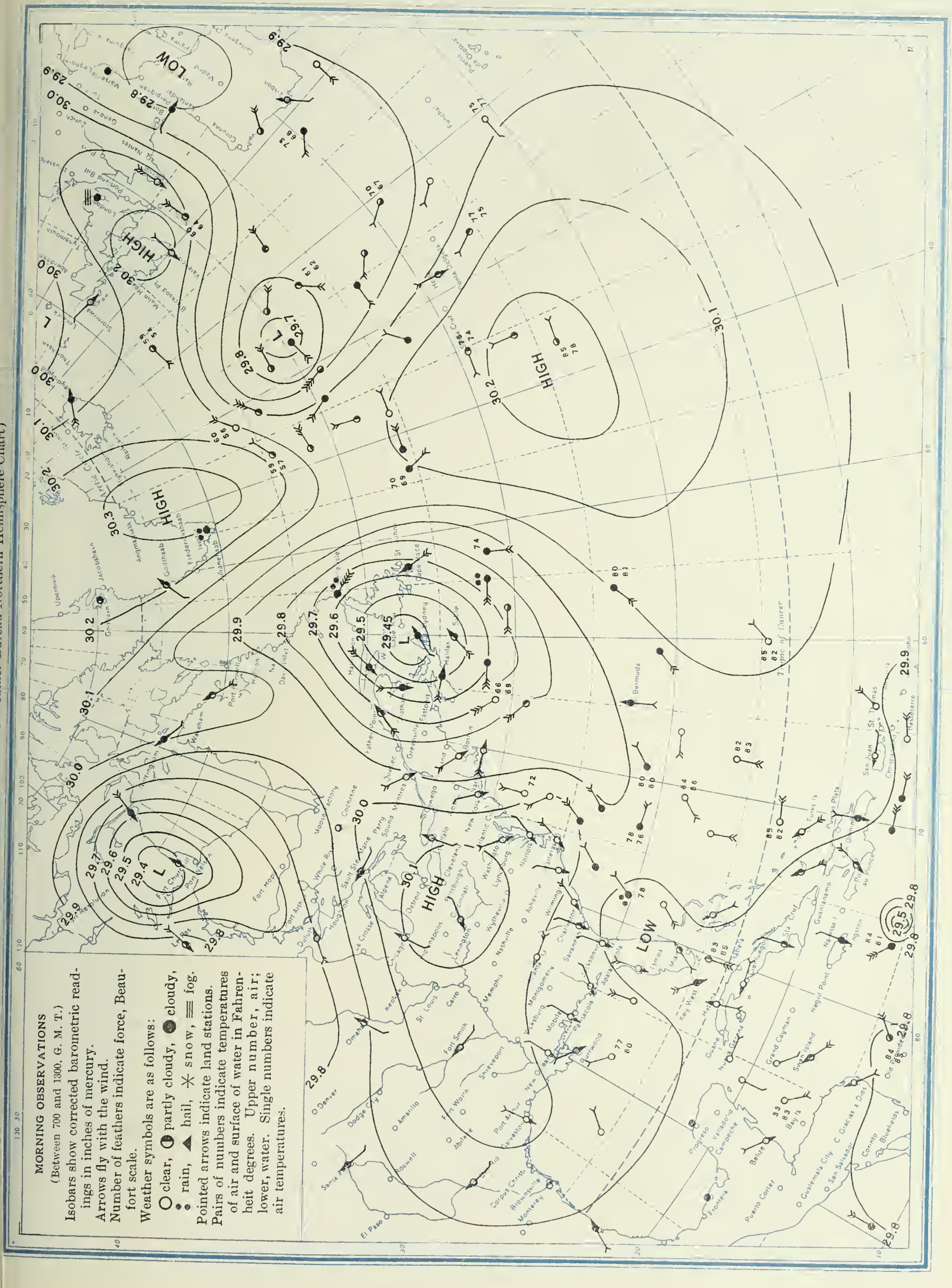
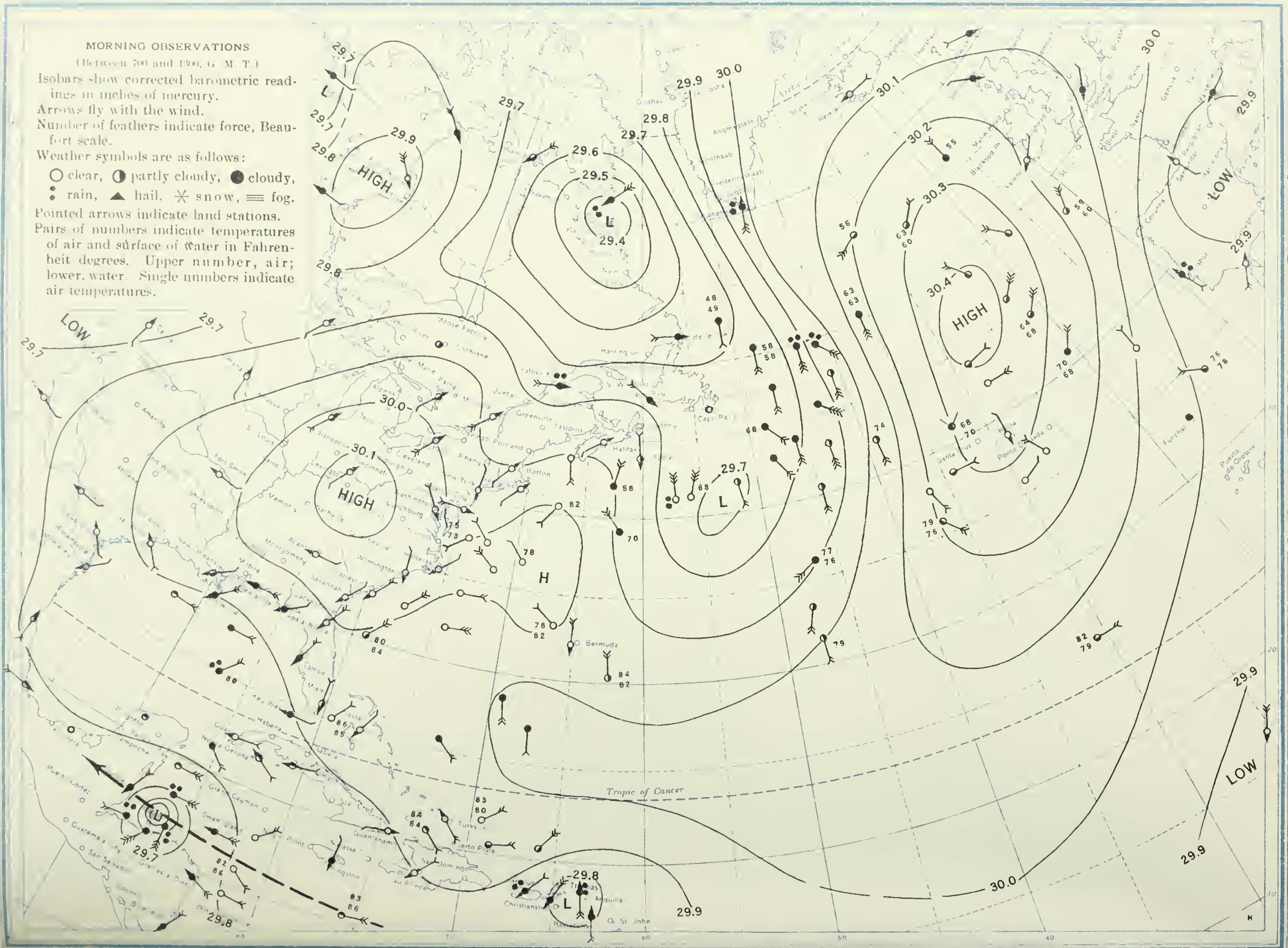

MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◐ partly cloudy, ● cloudy, rain, ▲ hail, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.
HIGH
LOW
Bermuda
Tropic of Cancer

Chart IX. Weather Map of North Atlantic Ocean, September 10, 1931
(Plotted from the Weather Bureau Northern Hemisphere Chart)



Bureau Northern Hemisphere Chart)

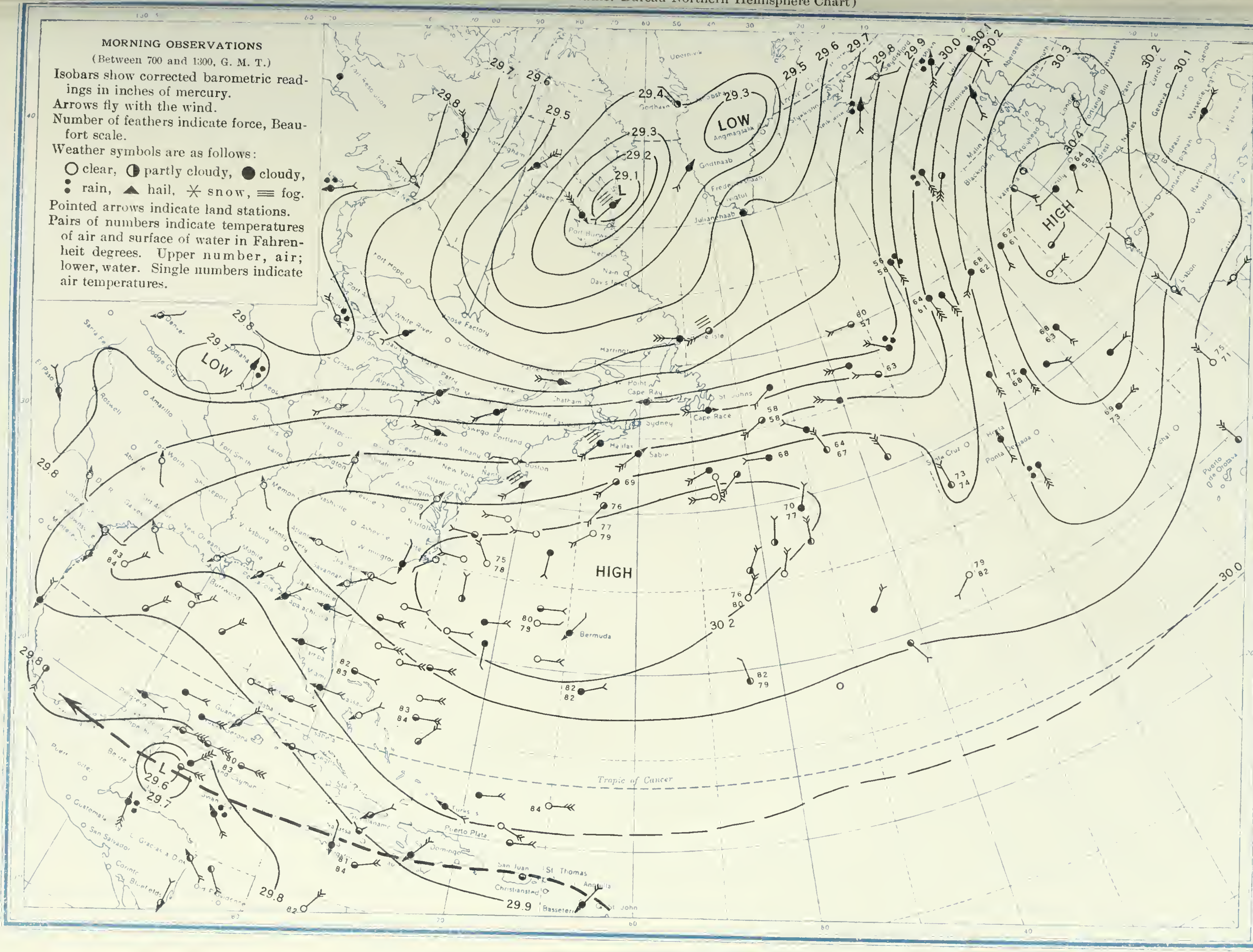
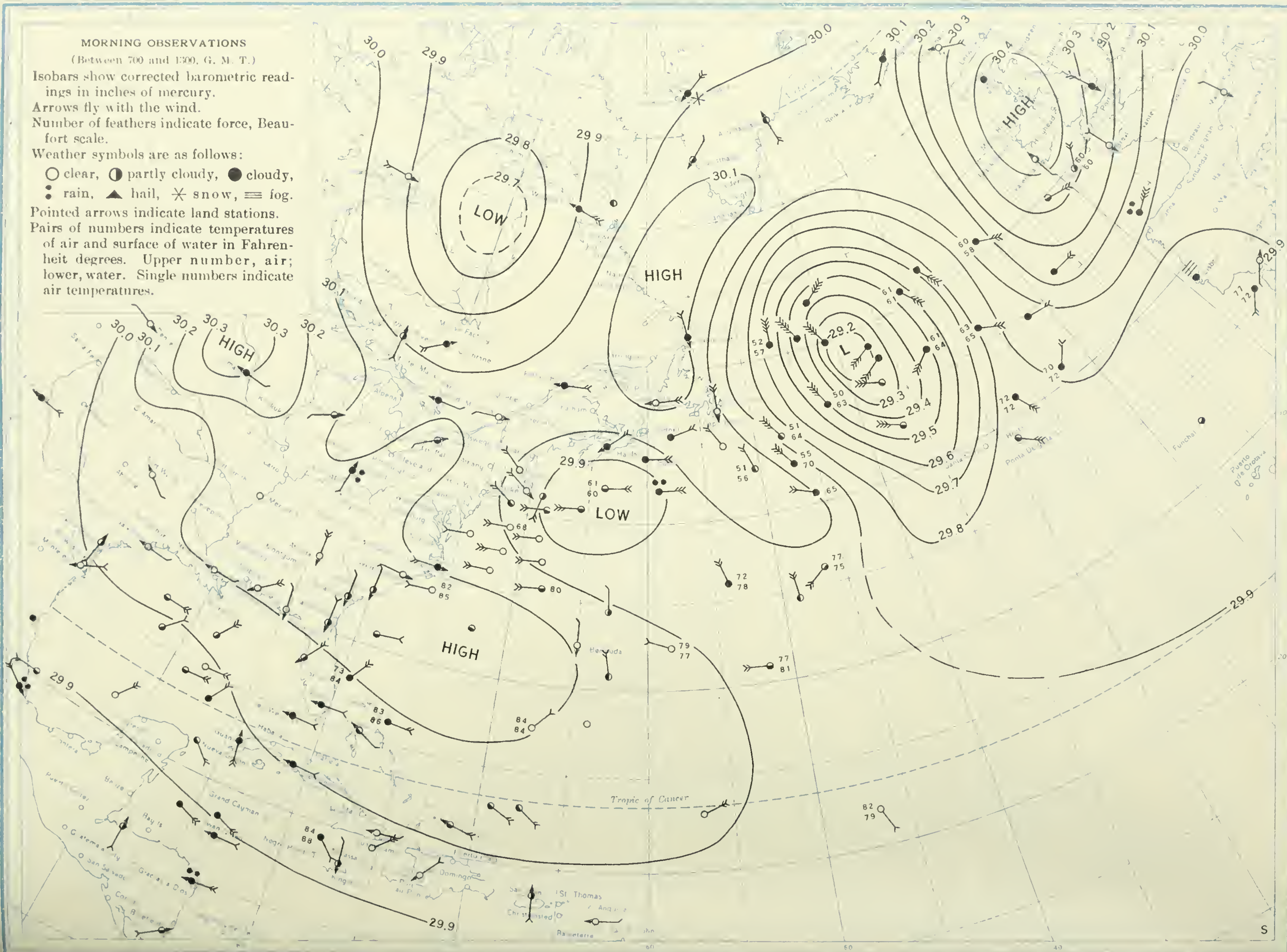


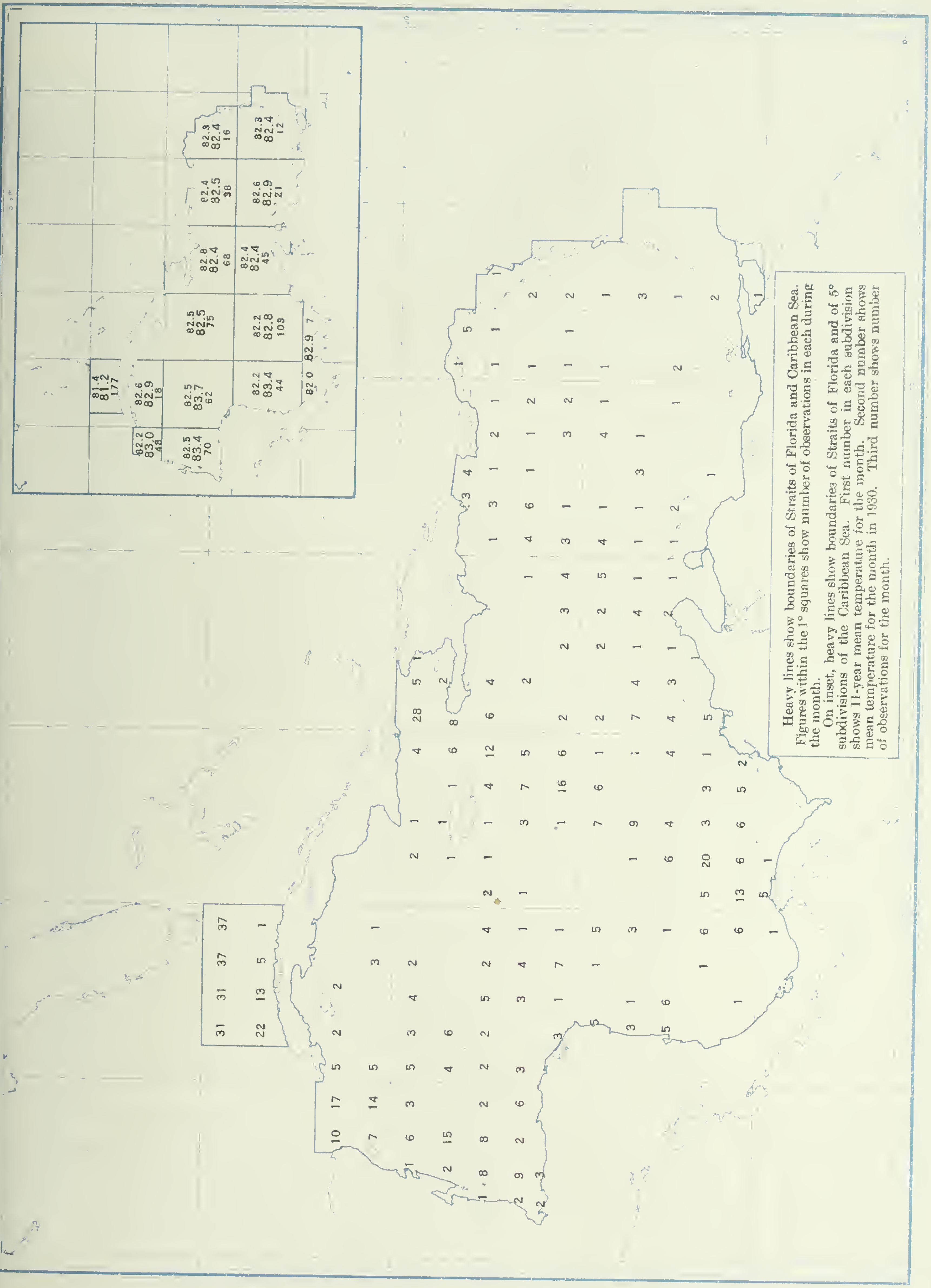
Chart XI. Weather Map of North Atlantic Ocean, September 23, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



Distribution of Greenwich Mean N[illegible] Temperatures, October, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, October, 1931

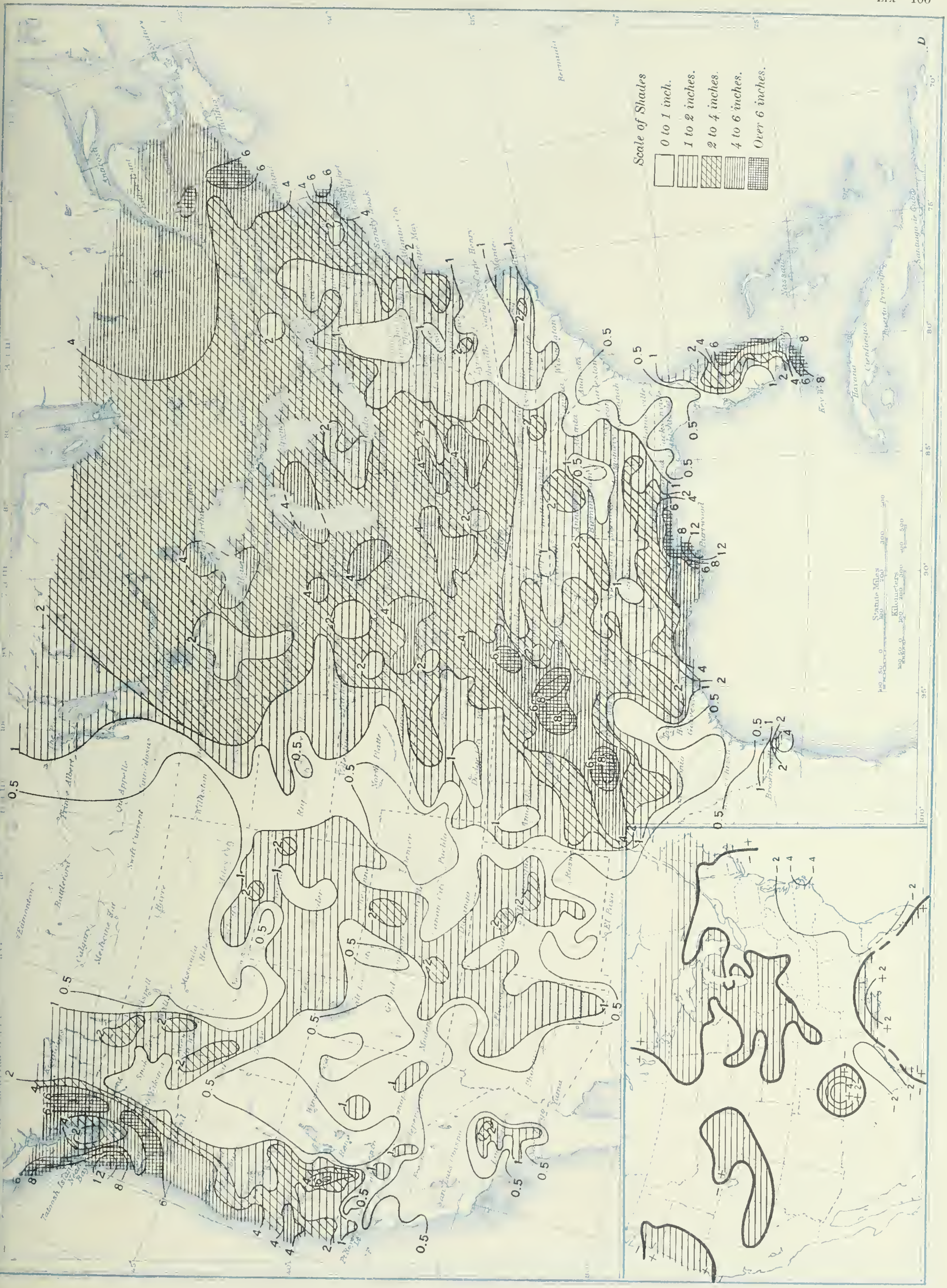
Chart II. Tracks of Centers of Anticyclones, October, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, October, 1931



Total Precipitation, Inches, October, 1931. (Inset) Departure of Precipitation from Normal

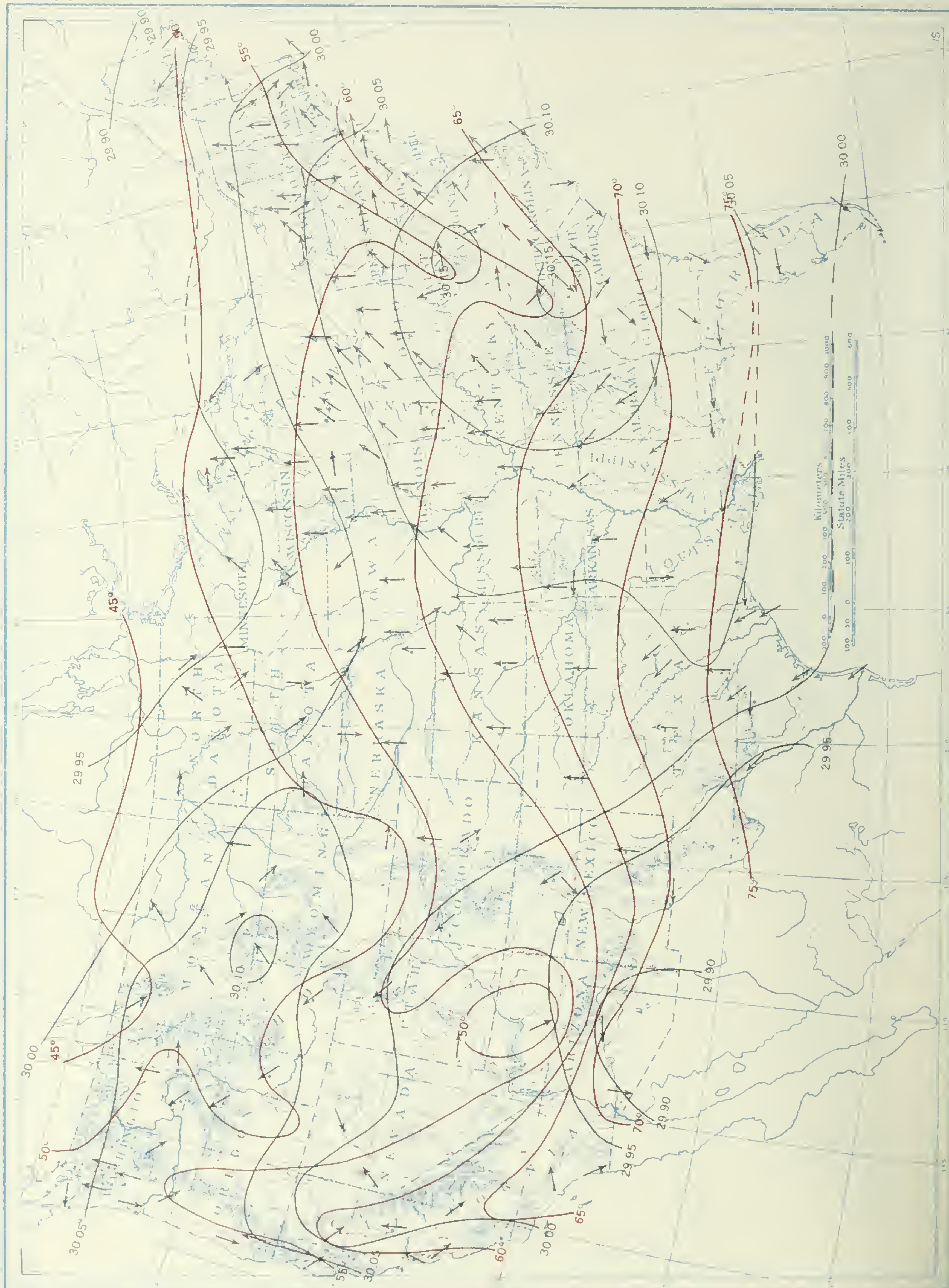


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, October, 1931

North Atlantic Ocean, October 22, 1931
(Plotted from the Weather Bureau Northern Hemisphere Chart)

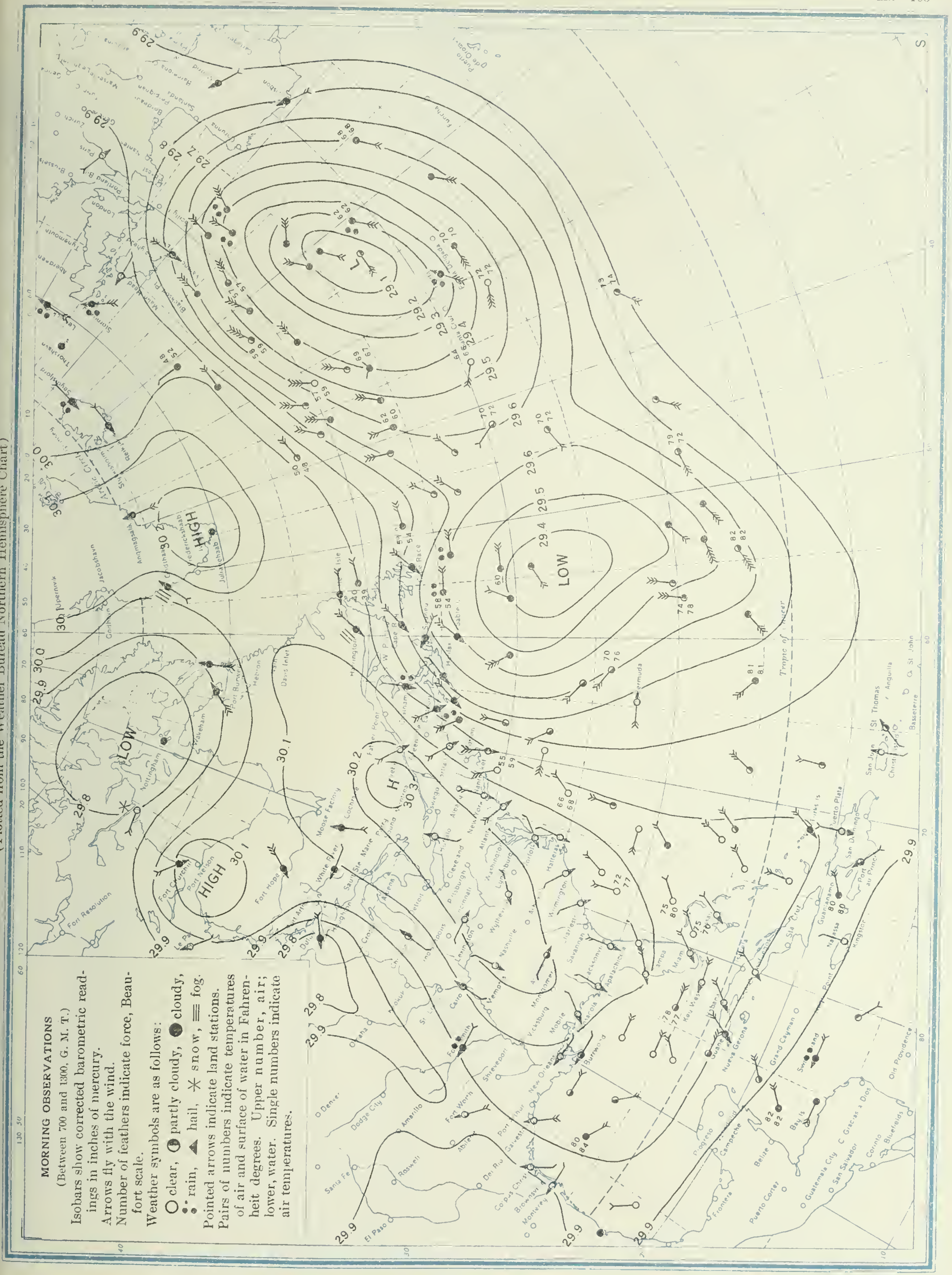
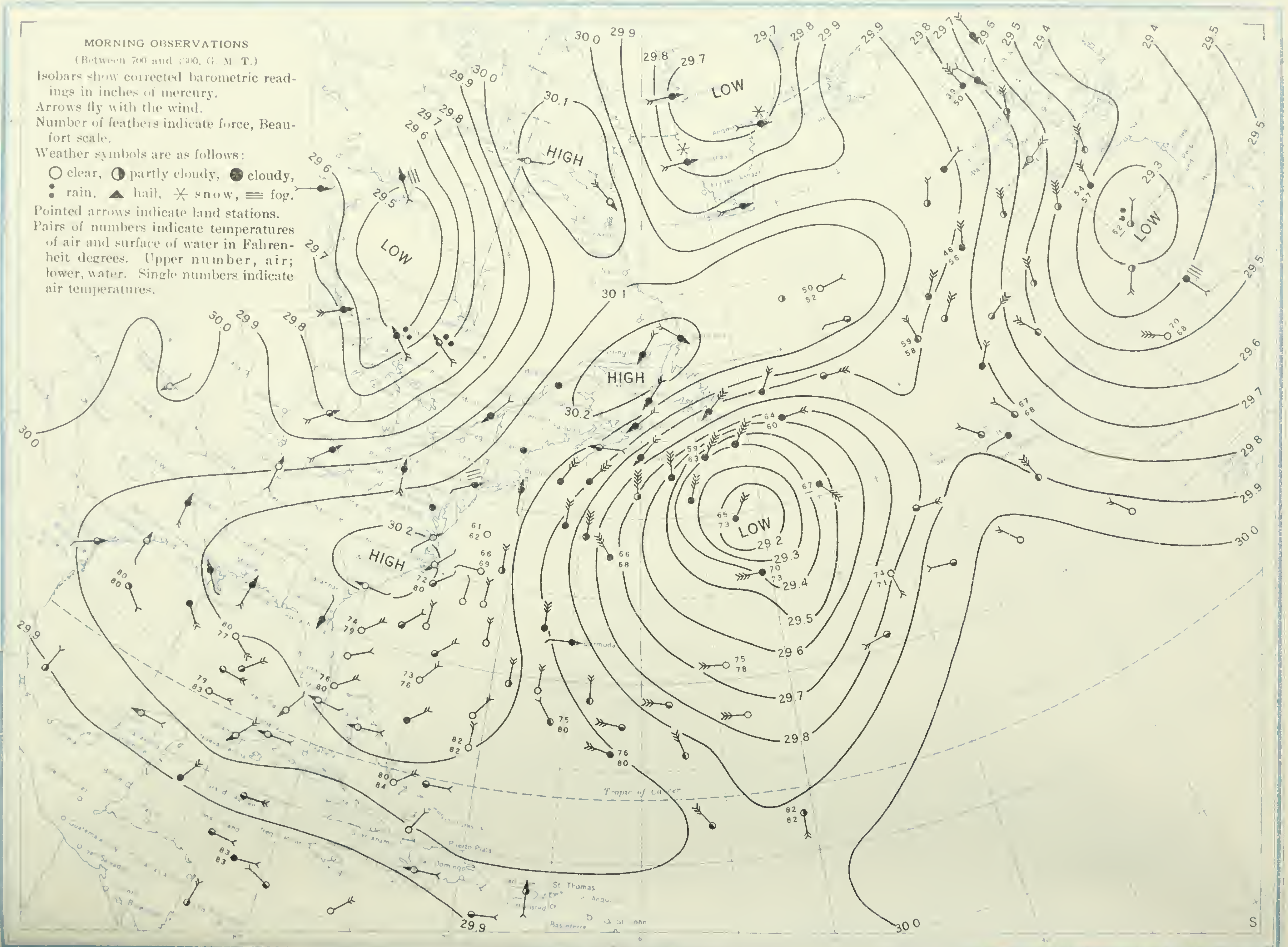


Chart IX. Weather Map of North Atlantic Ocean, October 24, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



Ocean, October 26, 1931
(Plotted from the Weather Bureau Northern Hemisphere Chart)

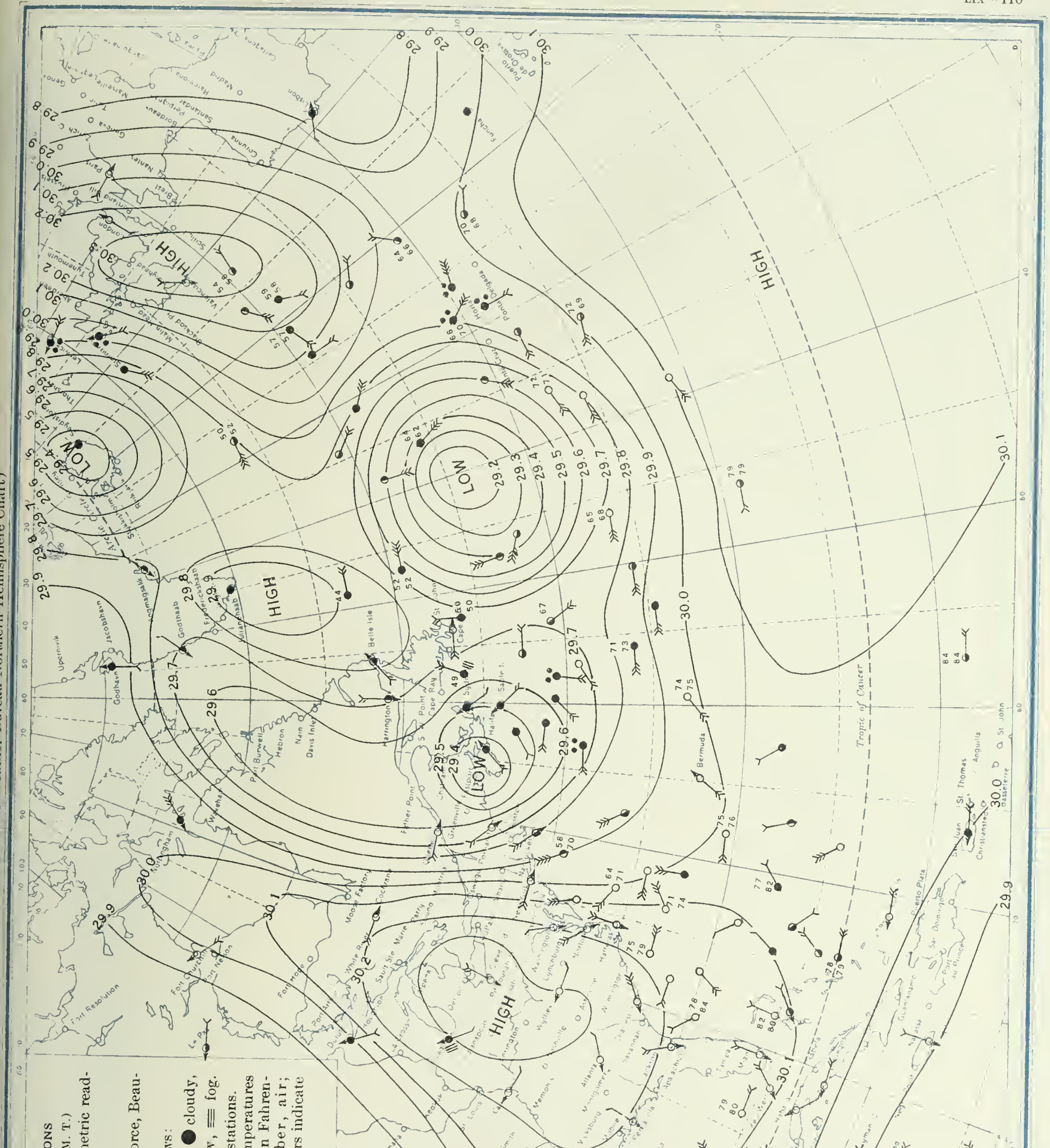
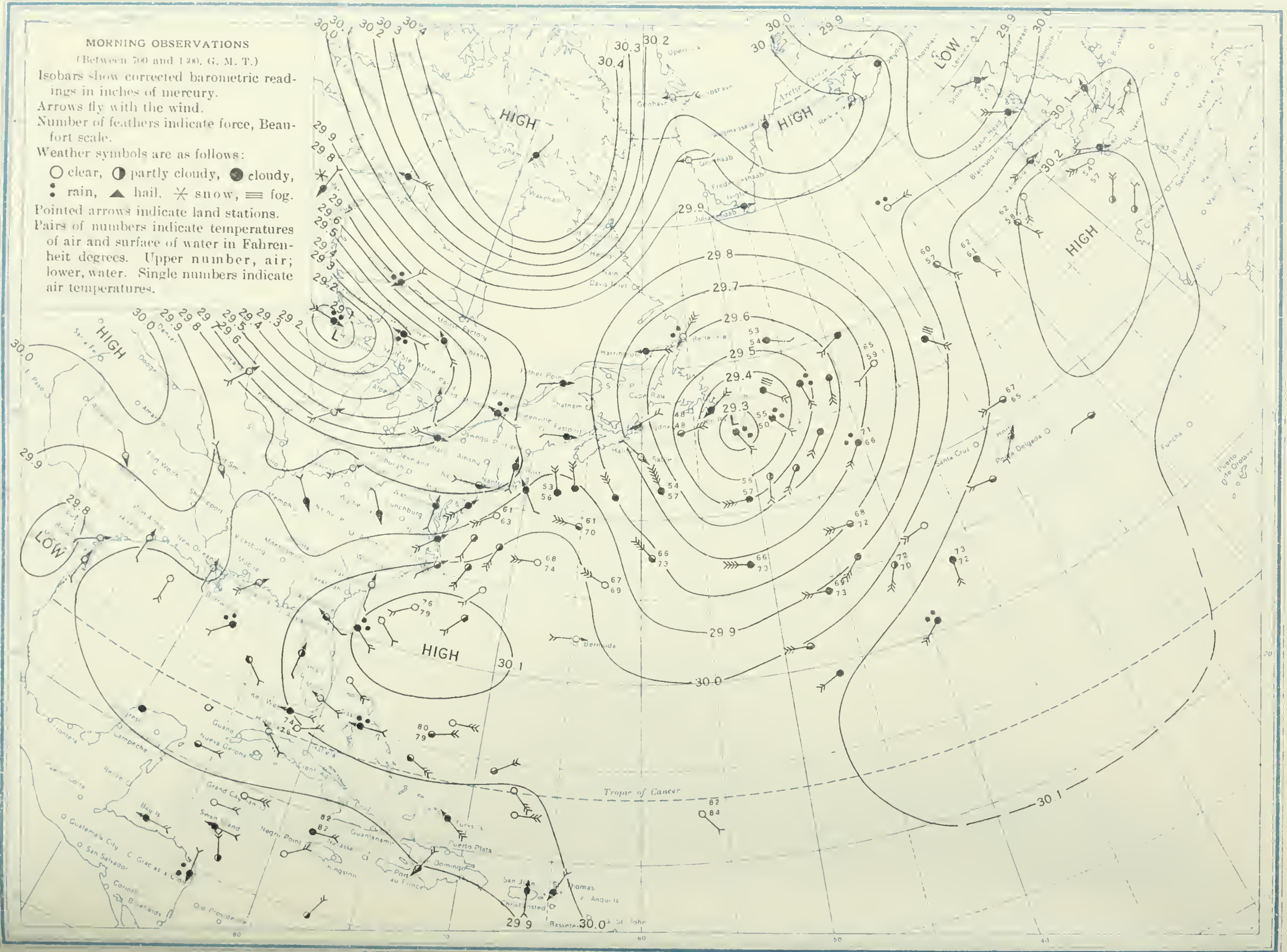


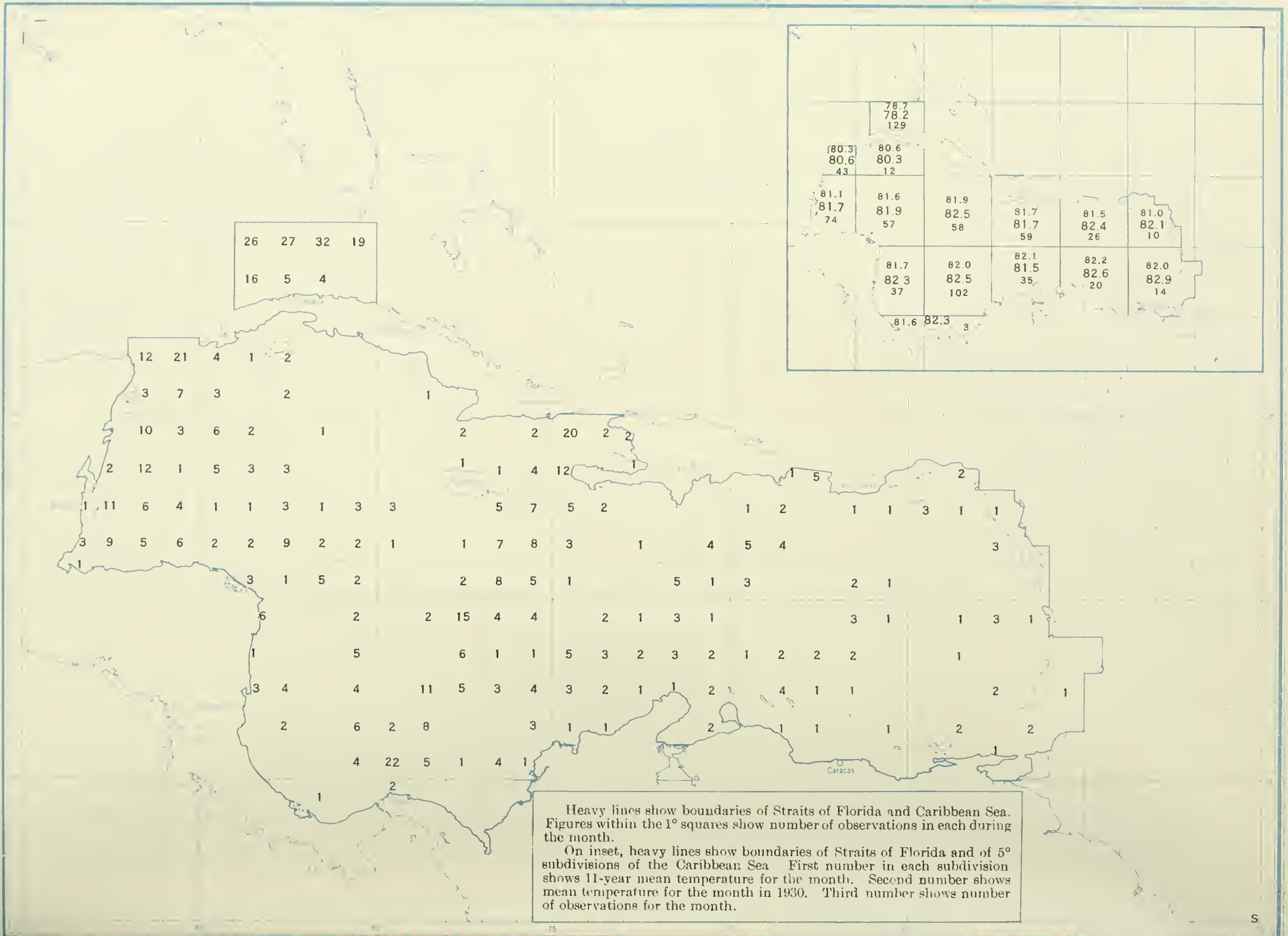
Chart XI. Weather Map of North Atlantic Ocean, October 28, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, November, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

of the Mean Temperature from the Normal, November, 1931

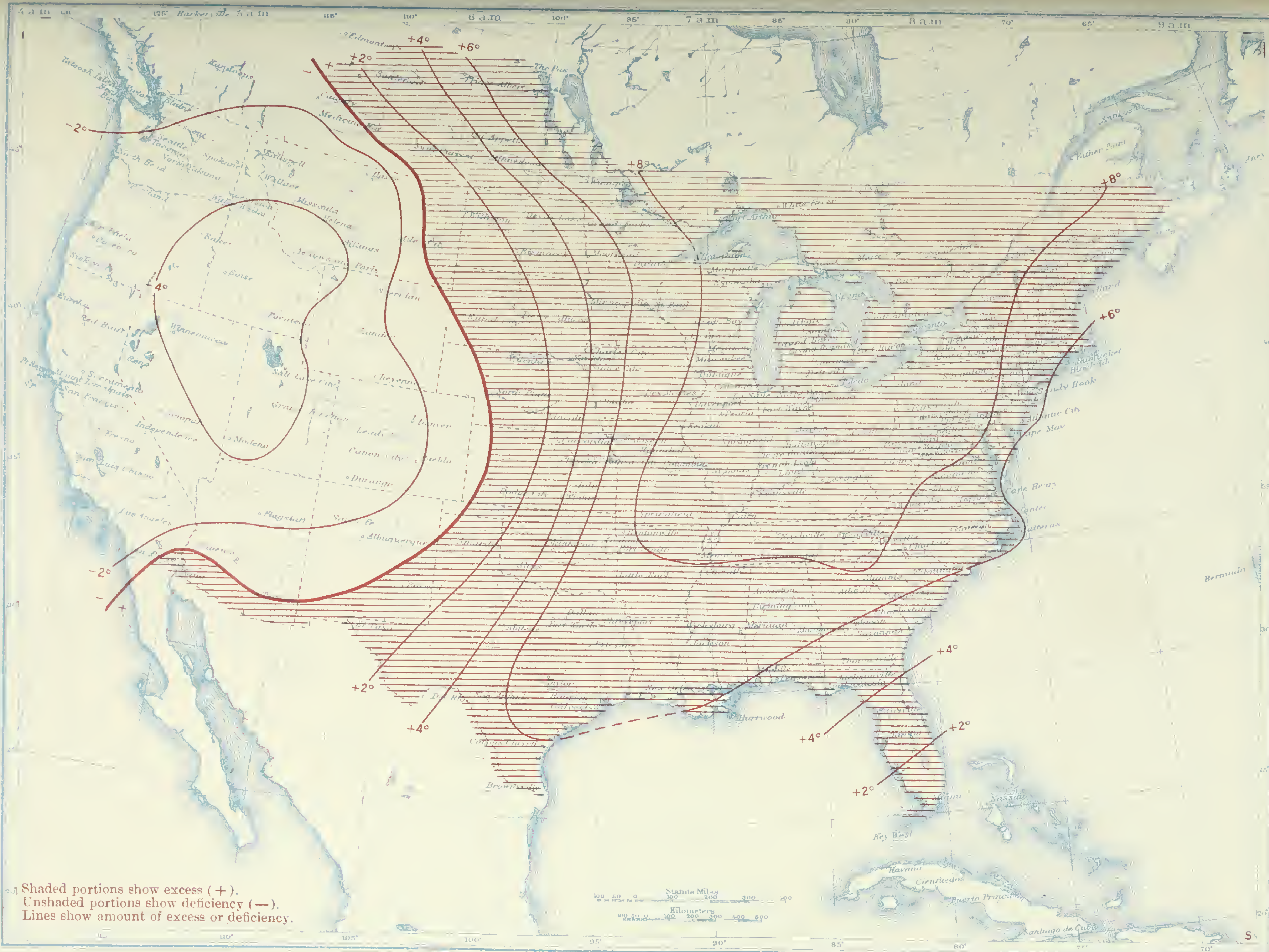
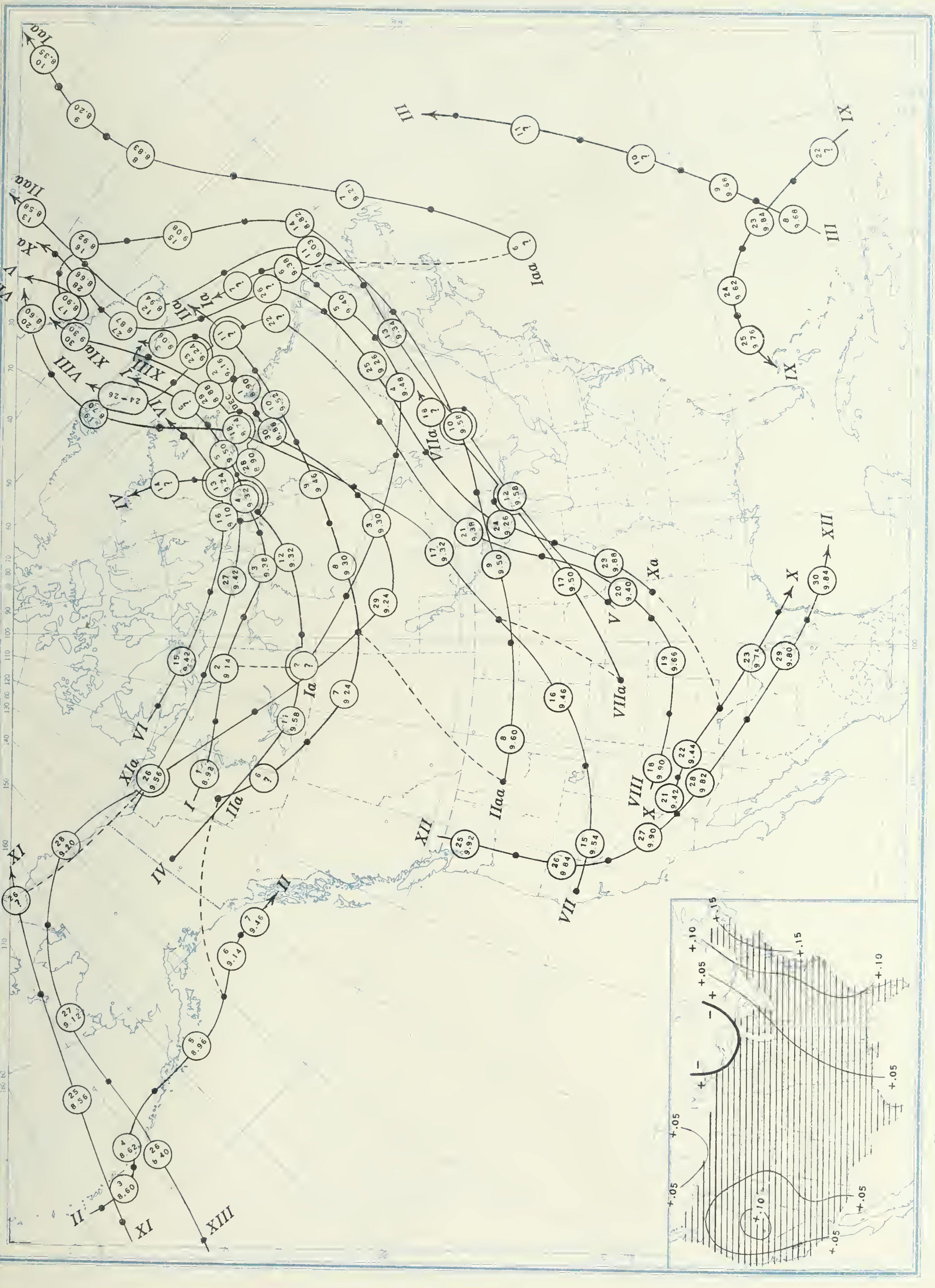


Chart II. Tracks of Centers of Anticyclones, November, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, November, 1931

Chart V. Total Precipitation, Inches, November, 1931. (Inset) Departure of Precipitation from Normal

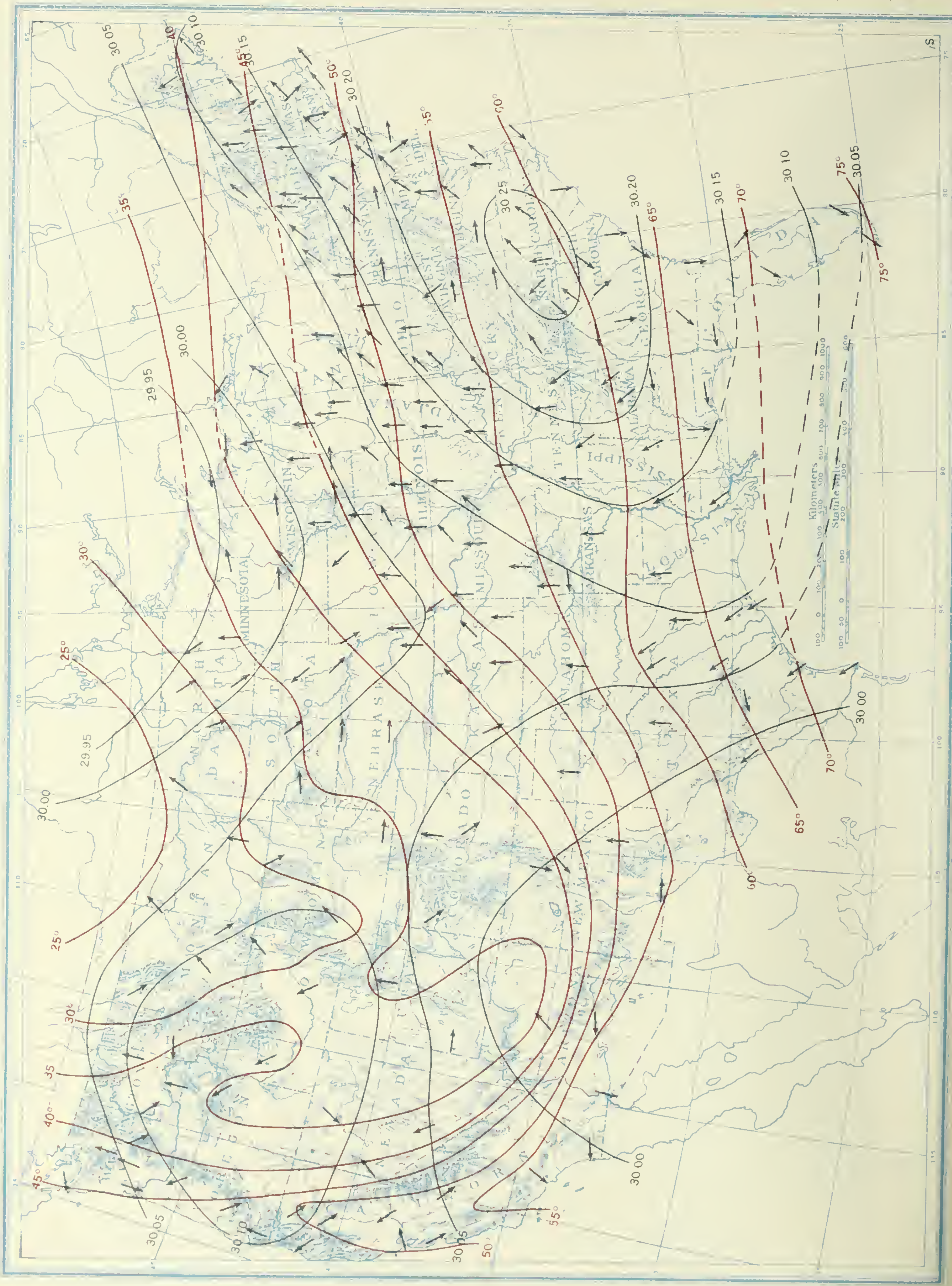


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, November, 1931

Chart VIII. Total Snowfall, Inches, November, 1931. (Inset) Depth of Snow on Ground at end of Month

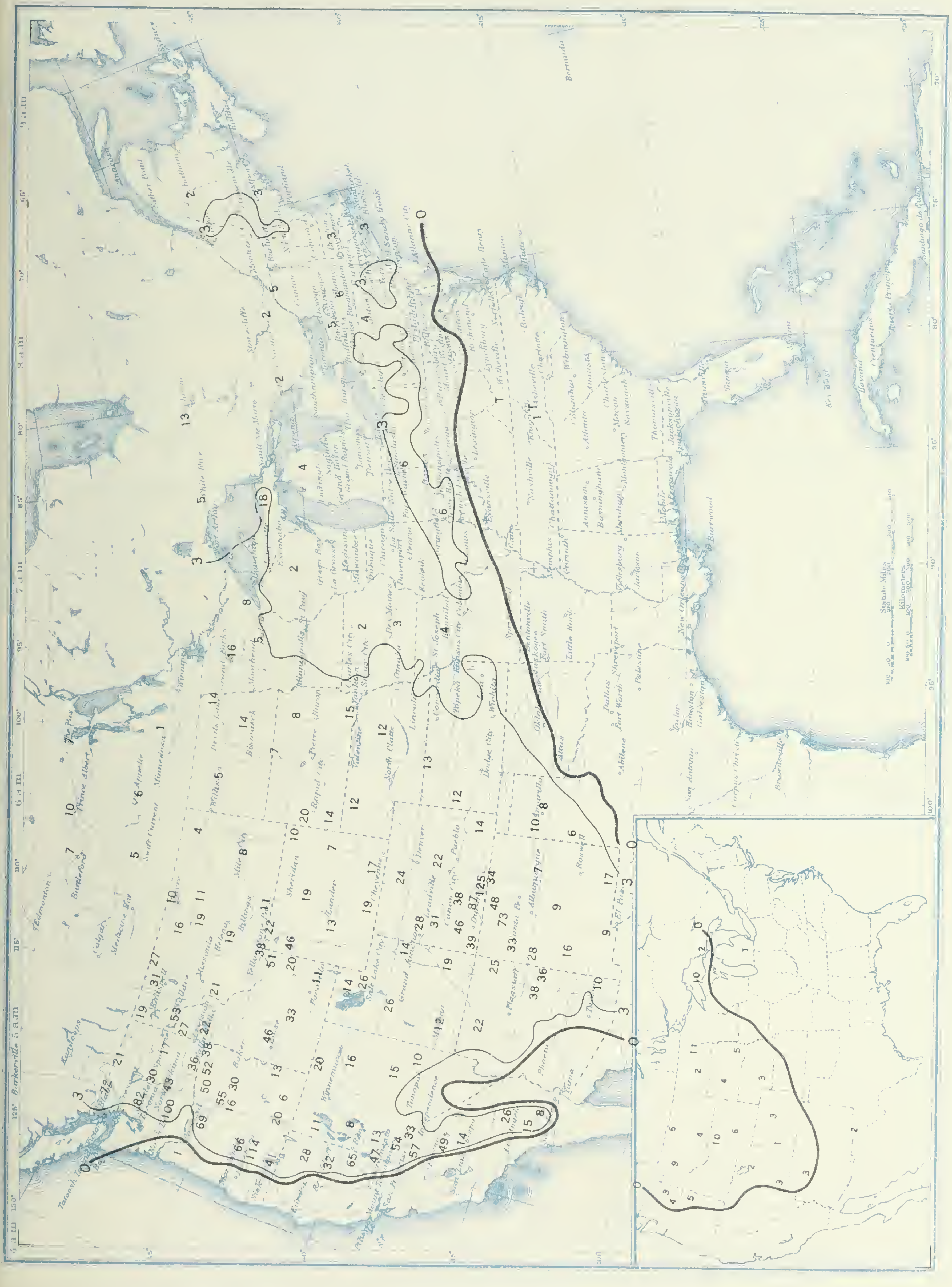


Chart VIII. Weather Map of North Atlantic Ocean, November 7, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)

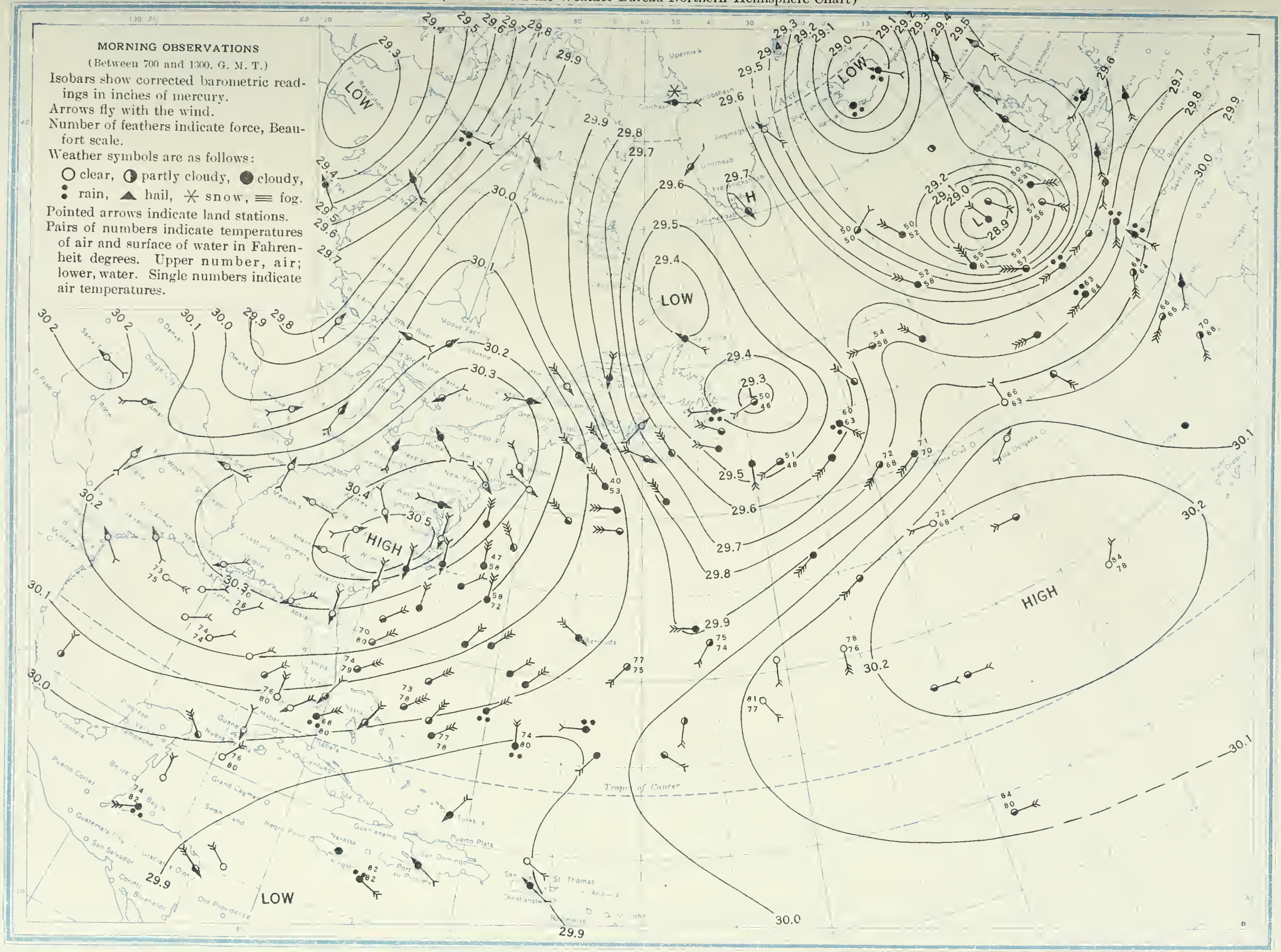


Chart IX. Weather Map of North Atlantic Ocean, November 8, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)

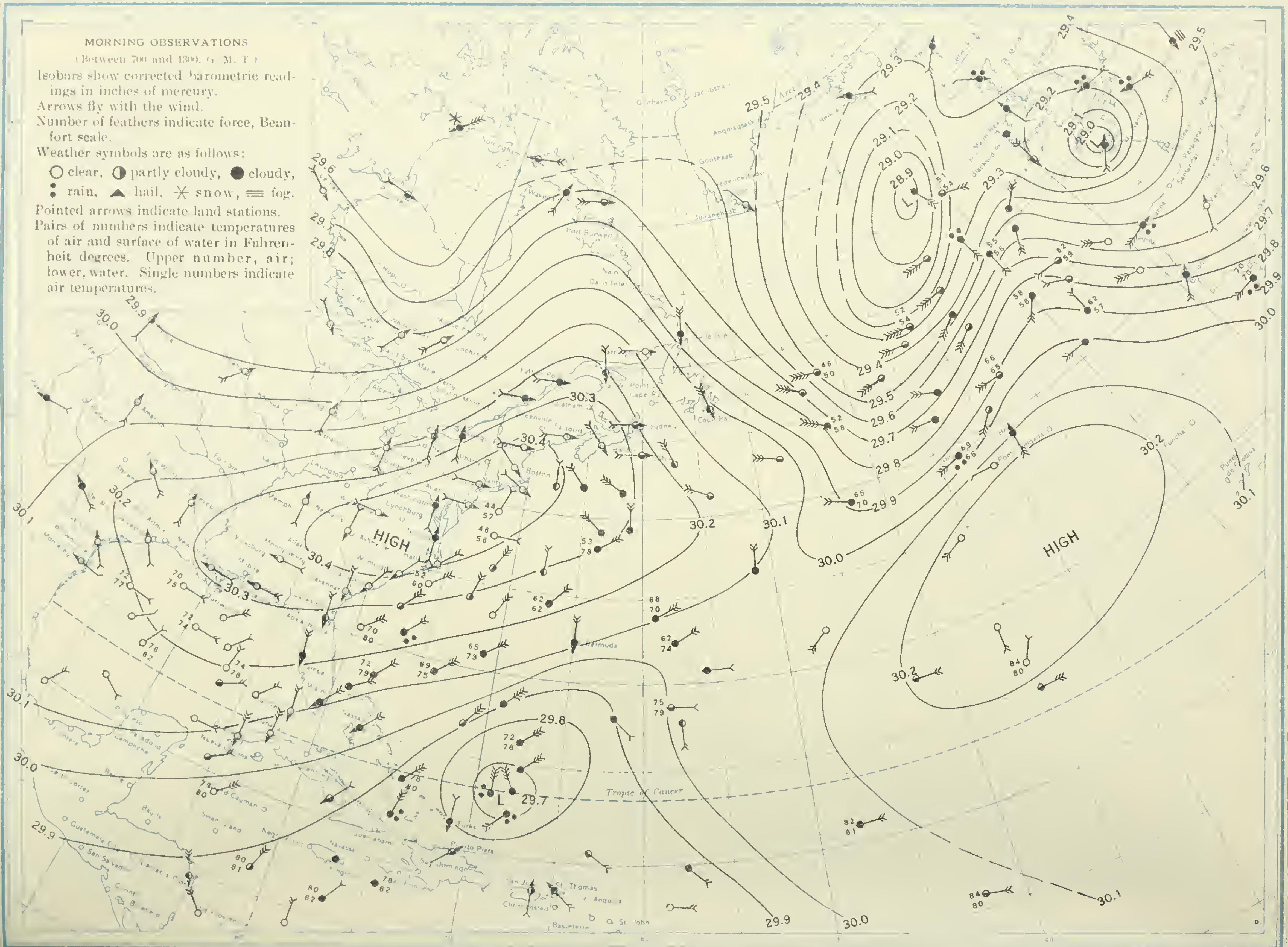


Chart X. Weather Map of North Atlantic Ocean, November 9, 1931
(Plotted from the Weather Bureau Northern Hemisphere Chart)

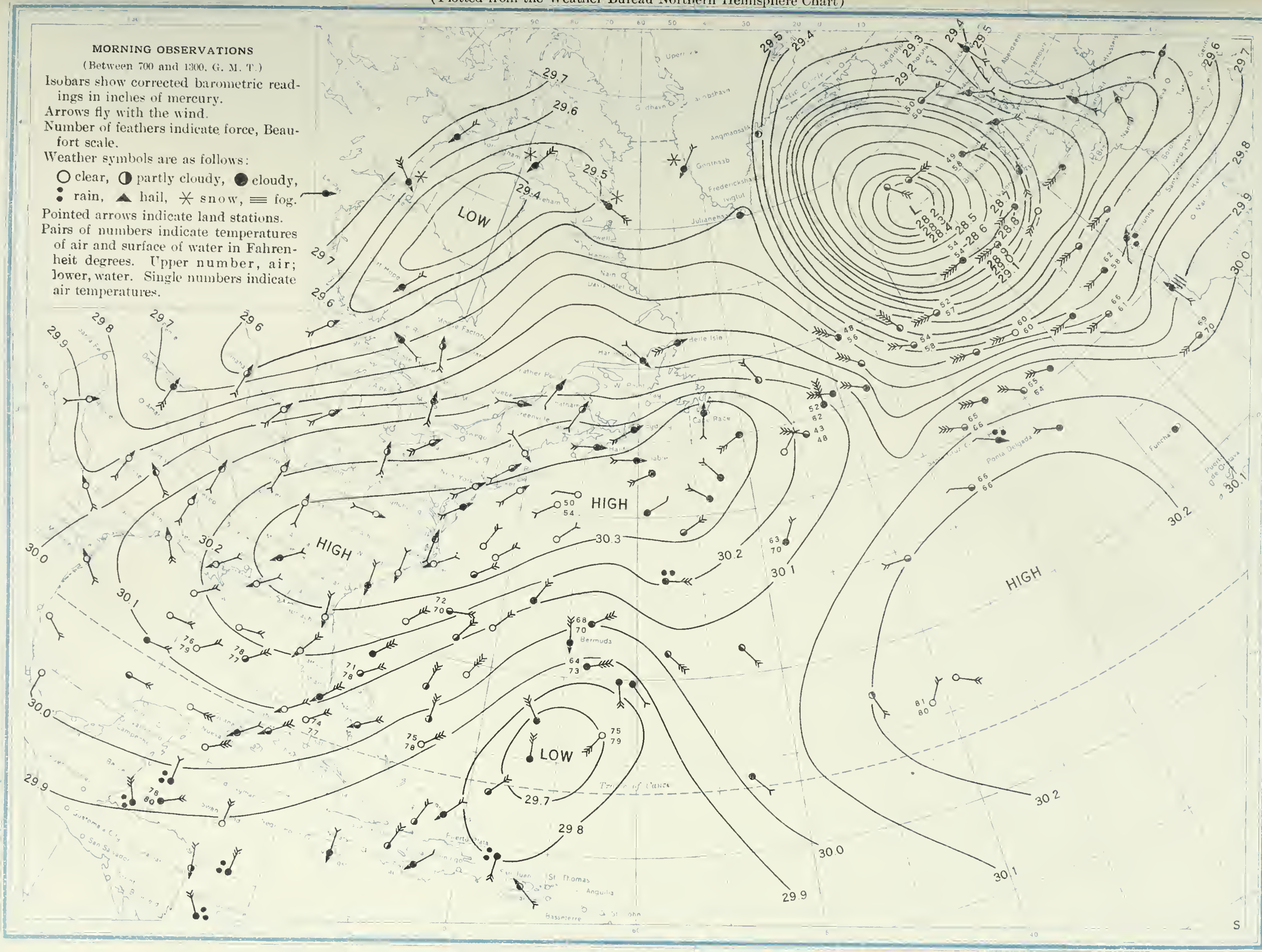
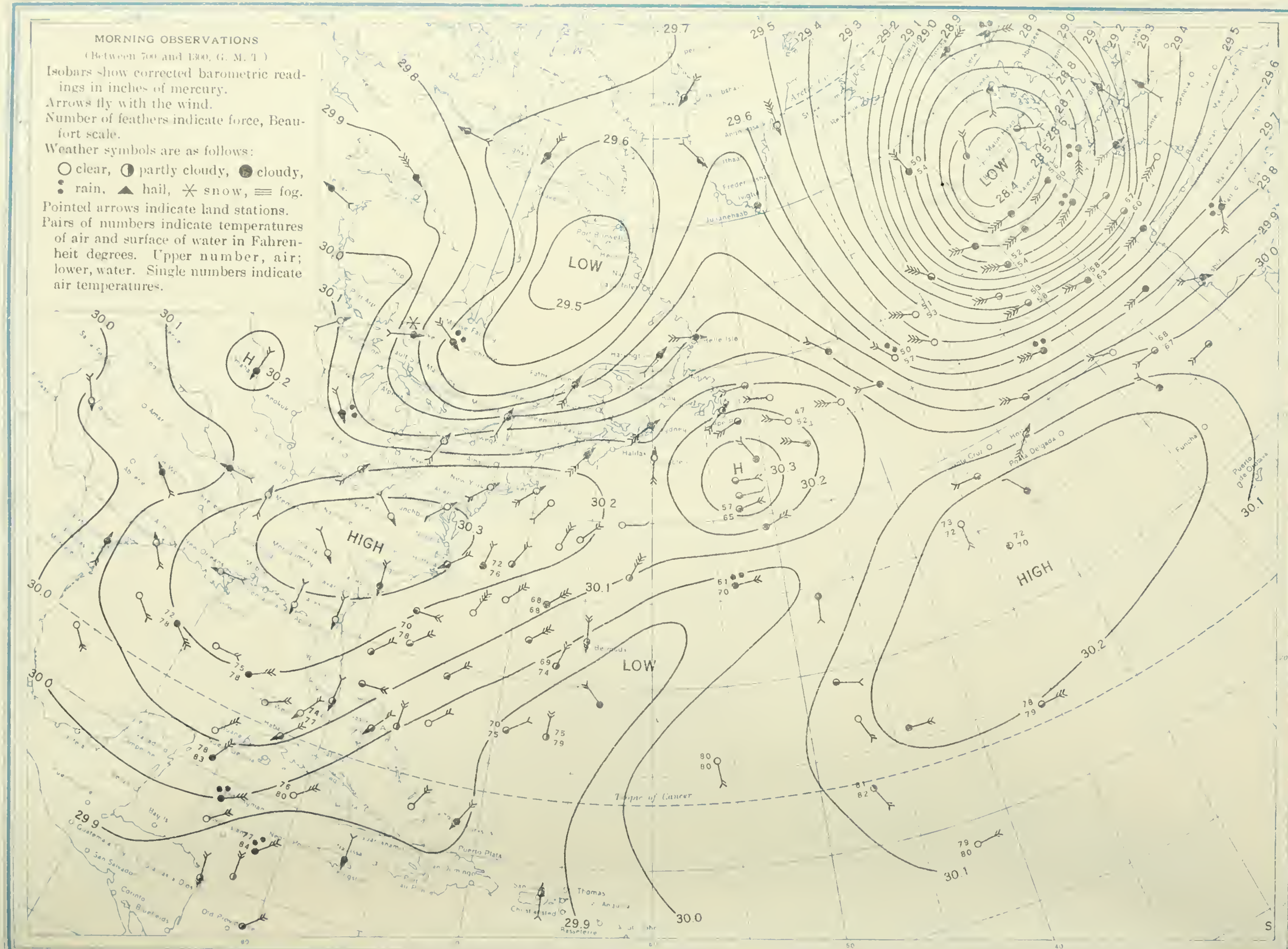
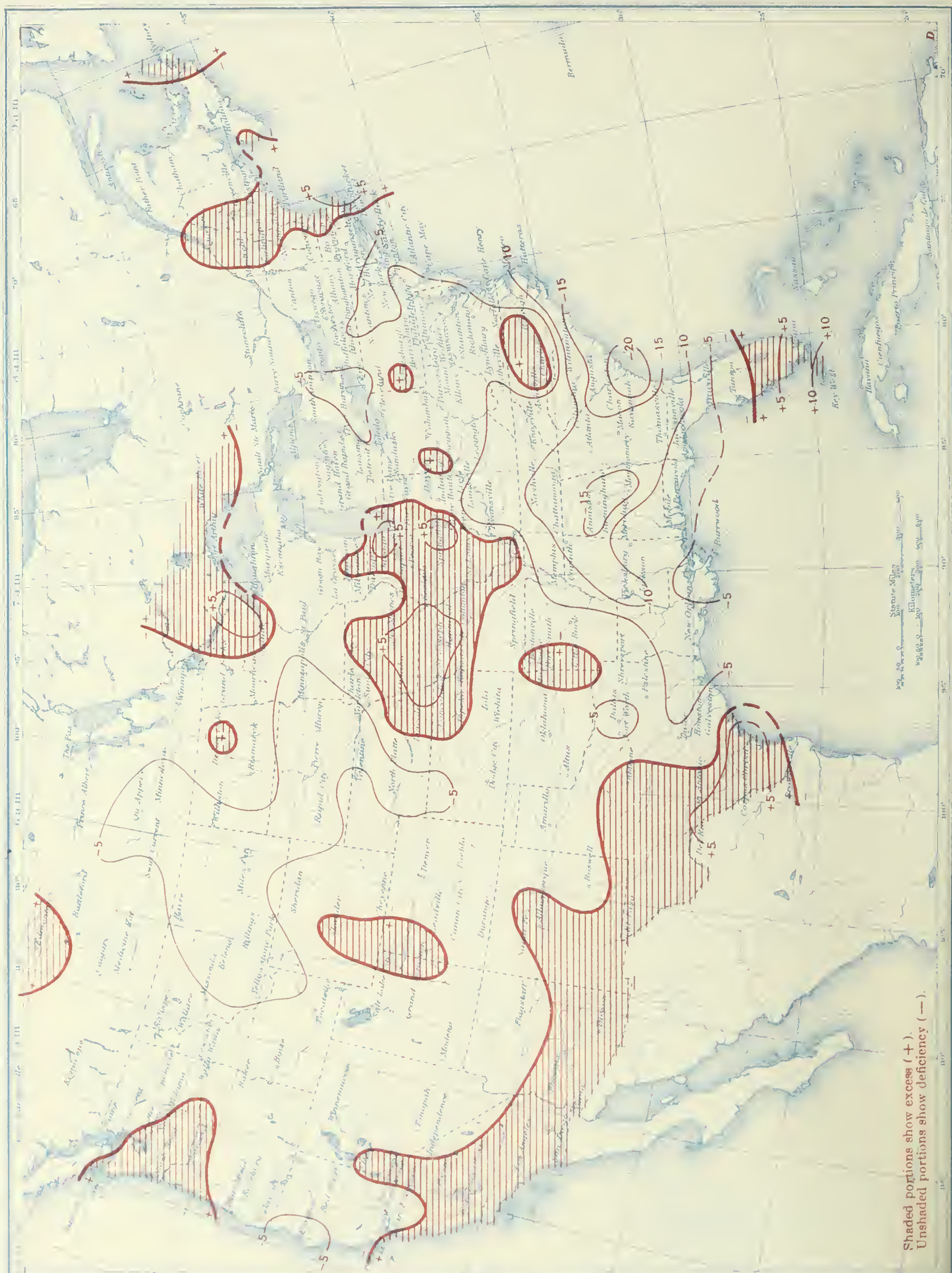


Chart XI. Weather Map of North Atlantic Ocean, November 10, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



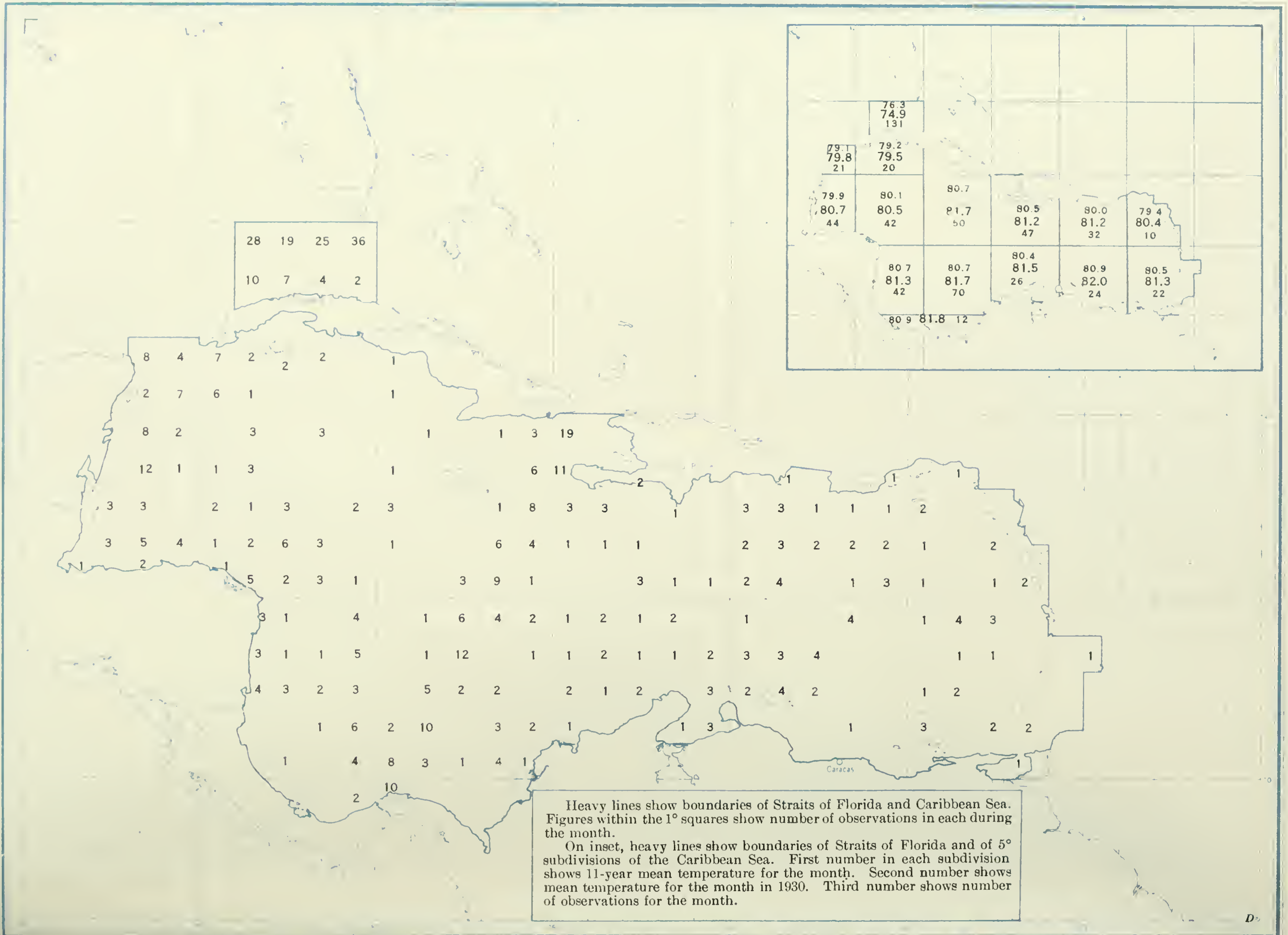

Shaded portions show excess (+).
Unshaded portions show deficiency (—).



II. Annual Precipitation Departures (inches) in the United States, 1931

Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, December, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

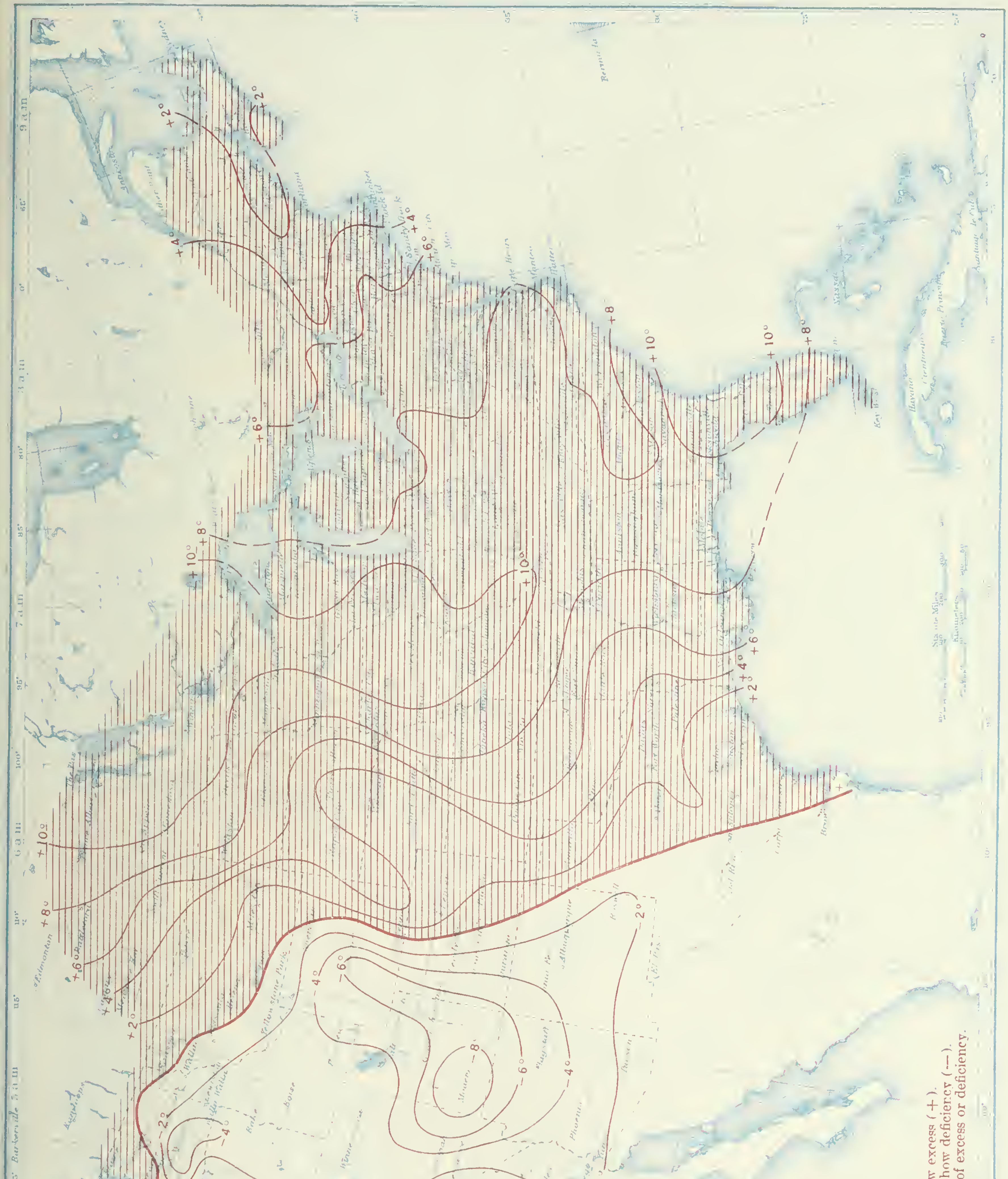
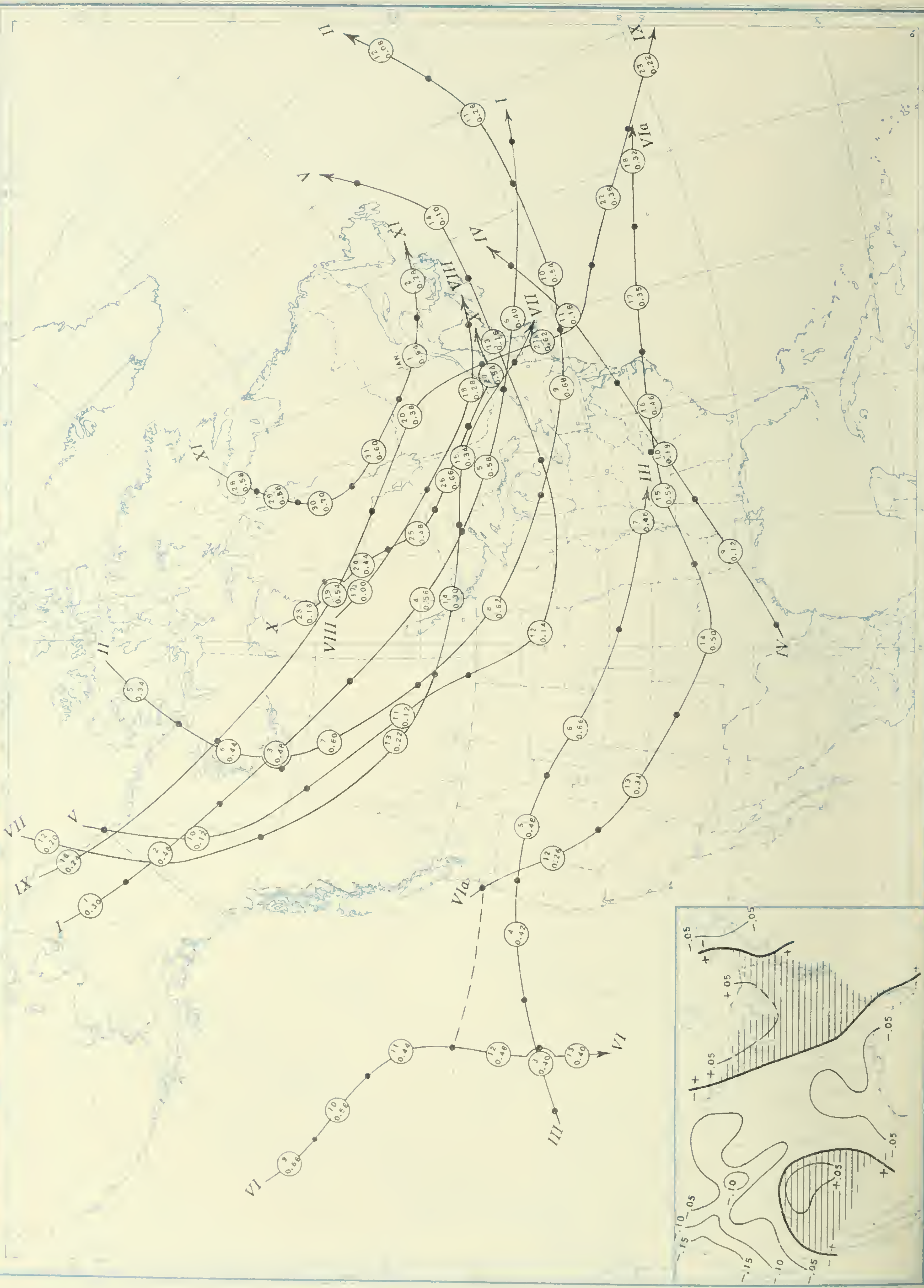

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, December, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

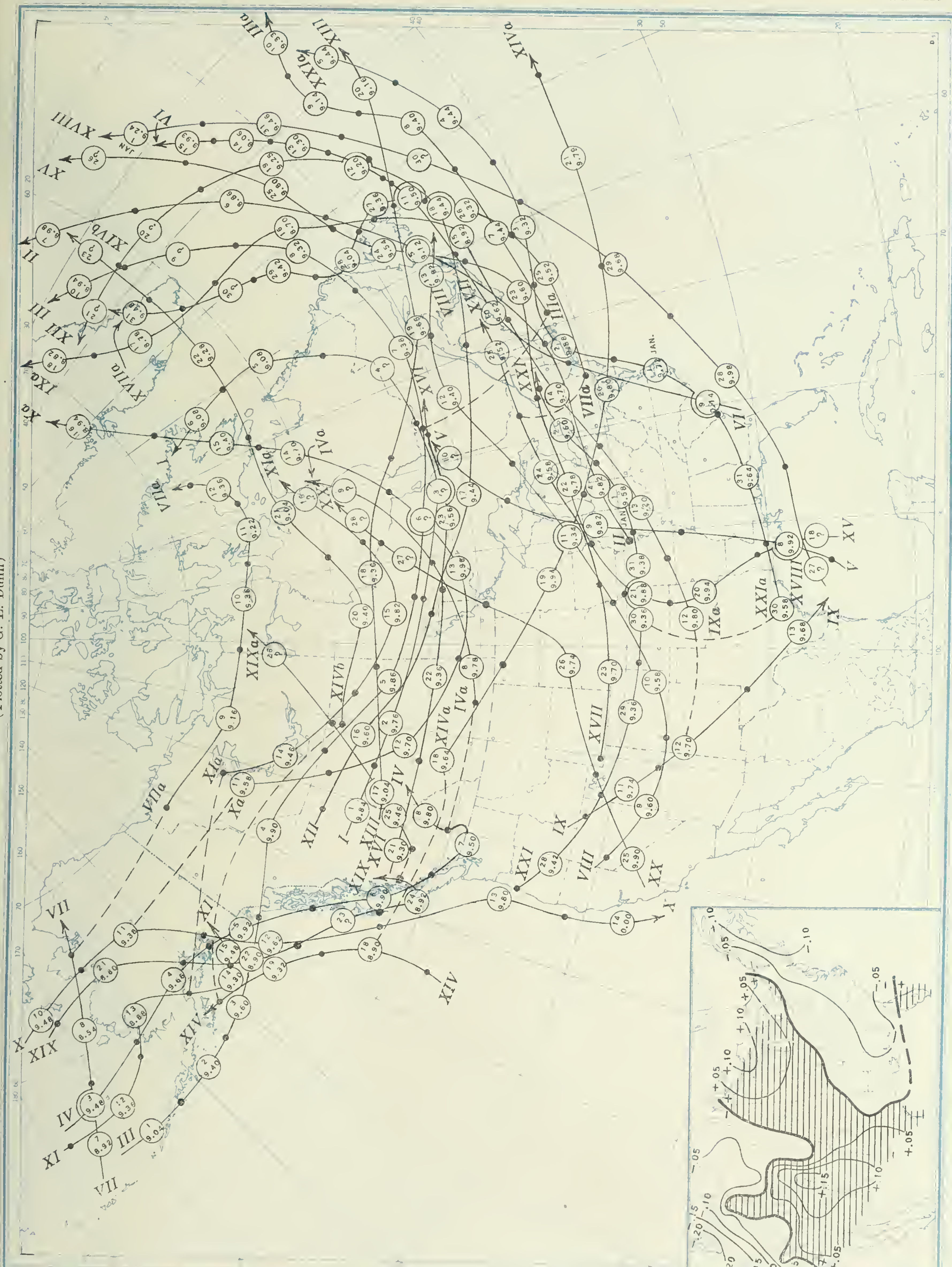
(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

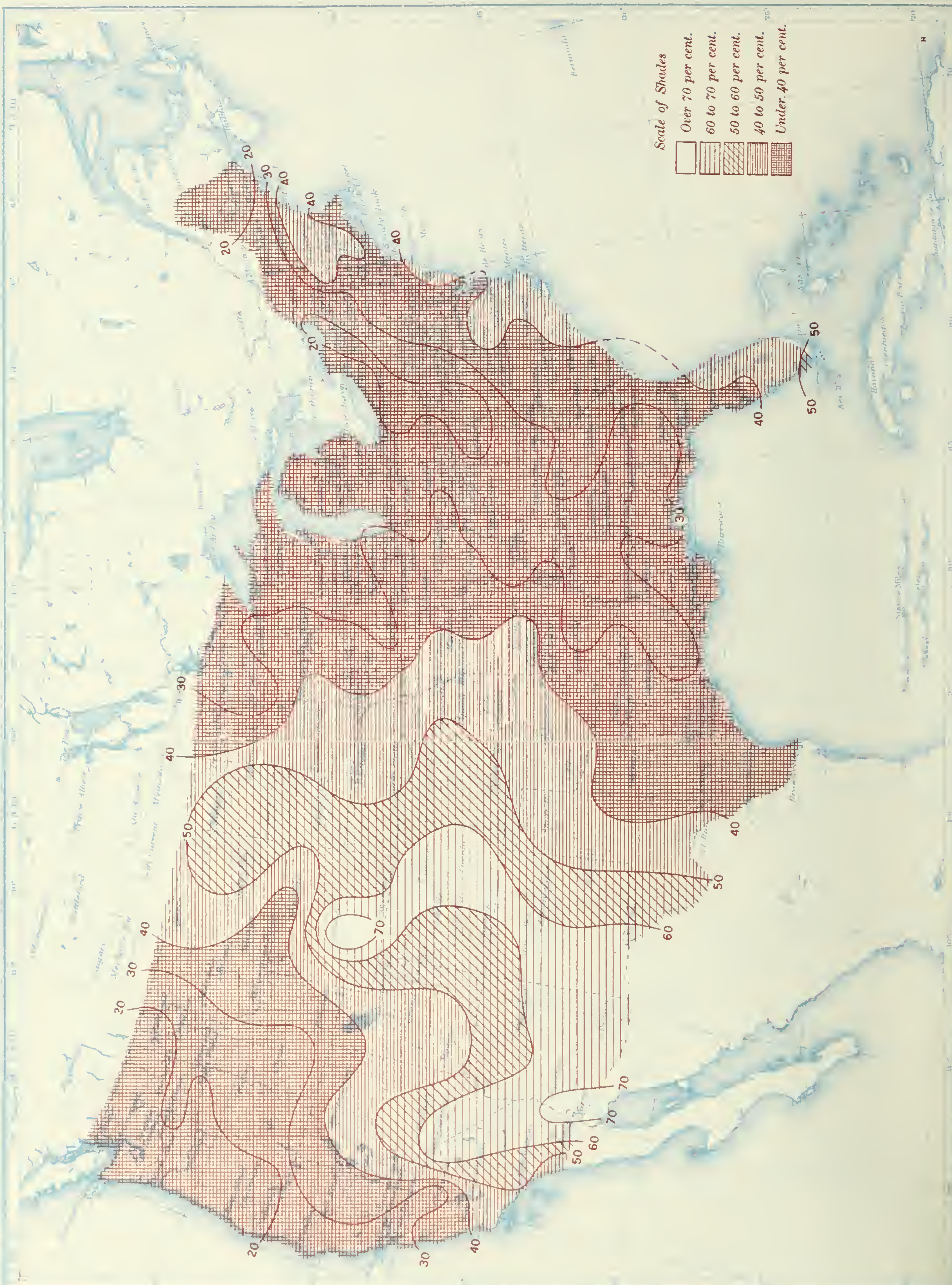
Chart III.—Tracks of Centers of Cyclones, December, 1931. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, December, 1931



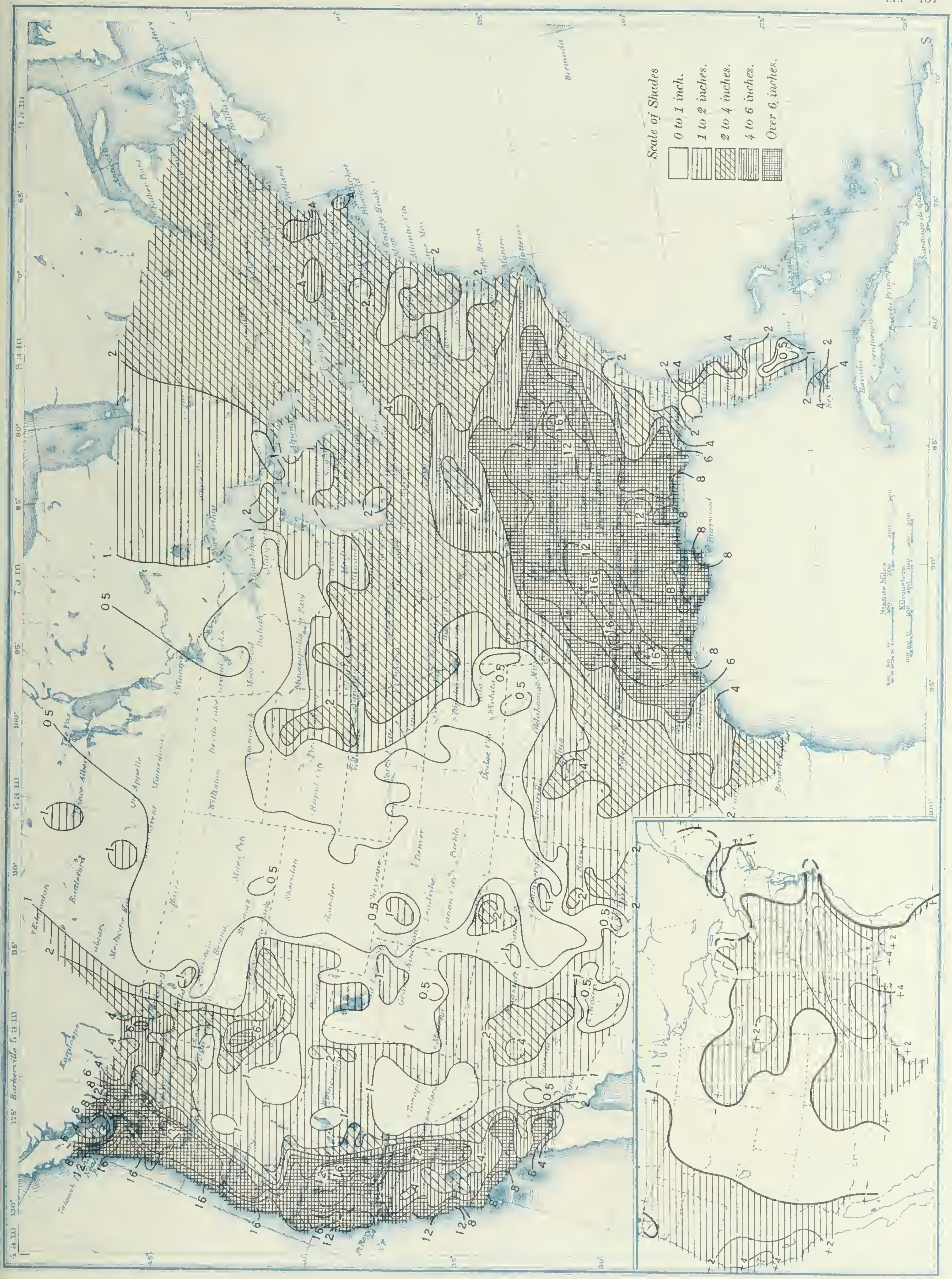
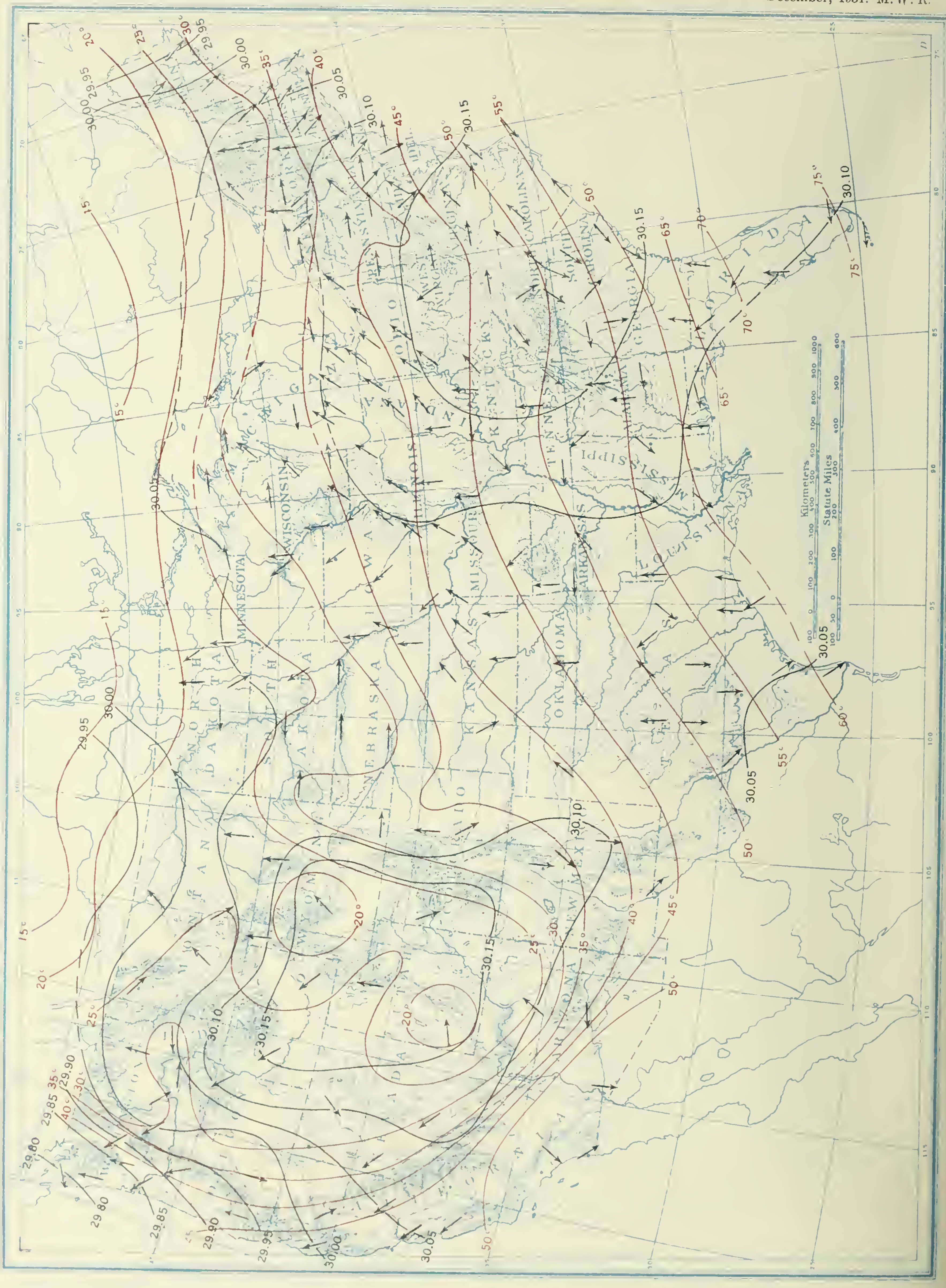
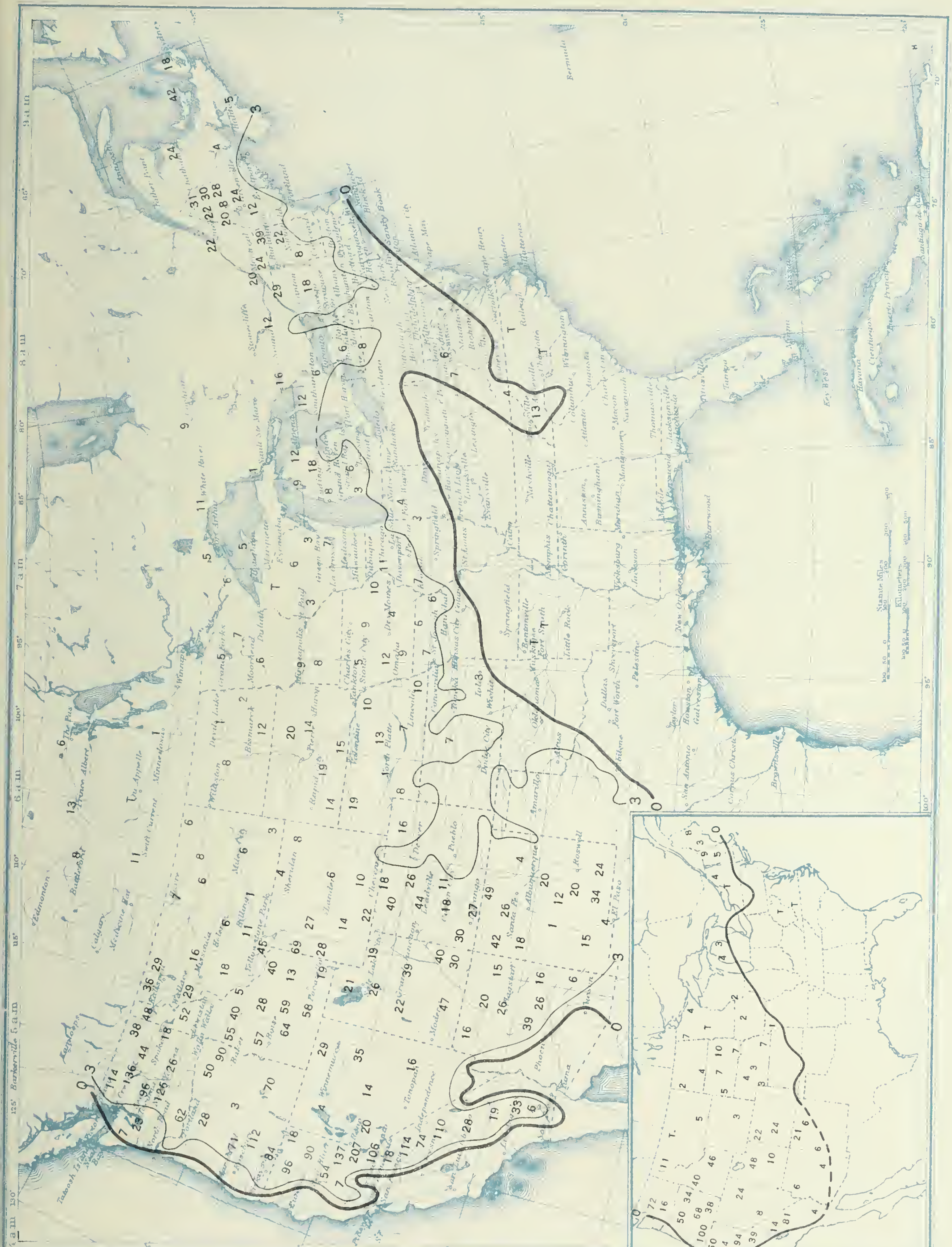

Scale of Shades
0 to 1 inch.
1 to 2 inches.
2 to 4 inches.
4 to 6 inches.
Over 6 inches.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, December, 1931



Depth of Snow on Ground at end of Month



(Plotted from the Weather Bureau Northern Hemisphere Chart)

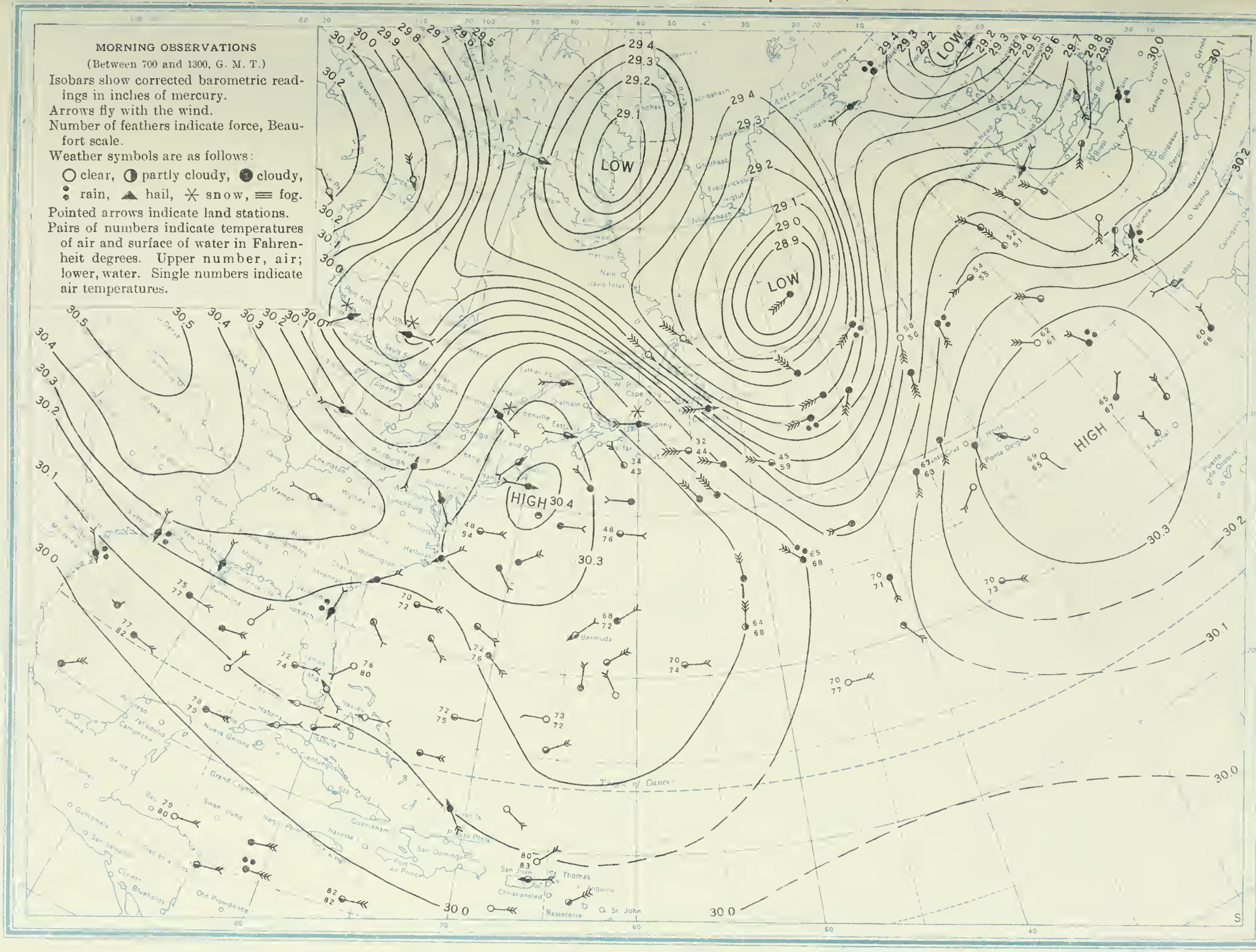
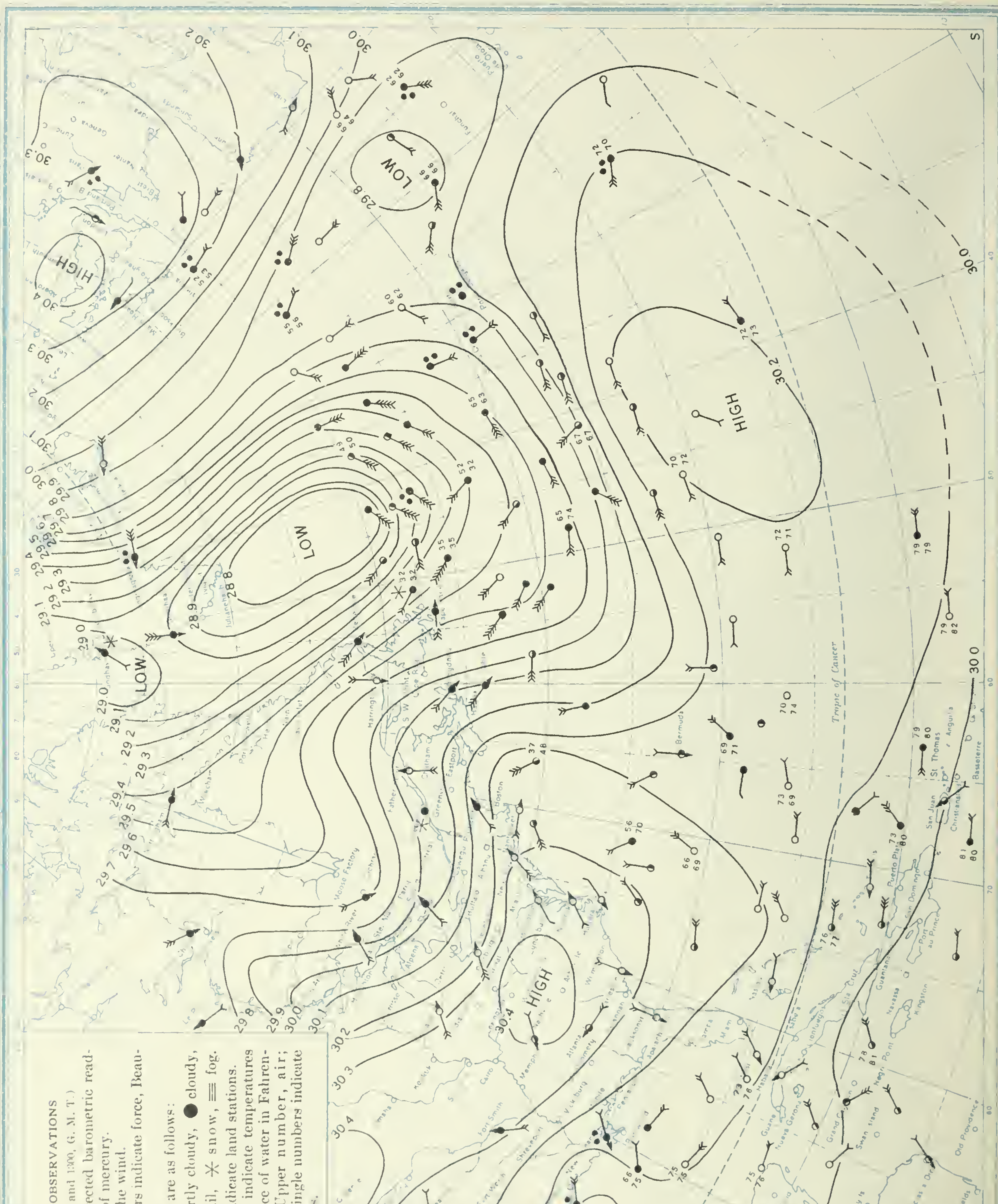


Chart IX. Weather Map of North Atlantic Ocean, December 16, 1931
(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

(Plotted from the Weather Bureau Northern Hemisphere Chart)

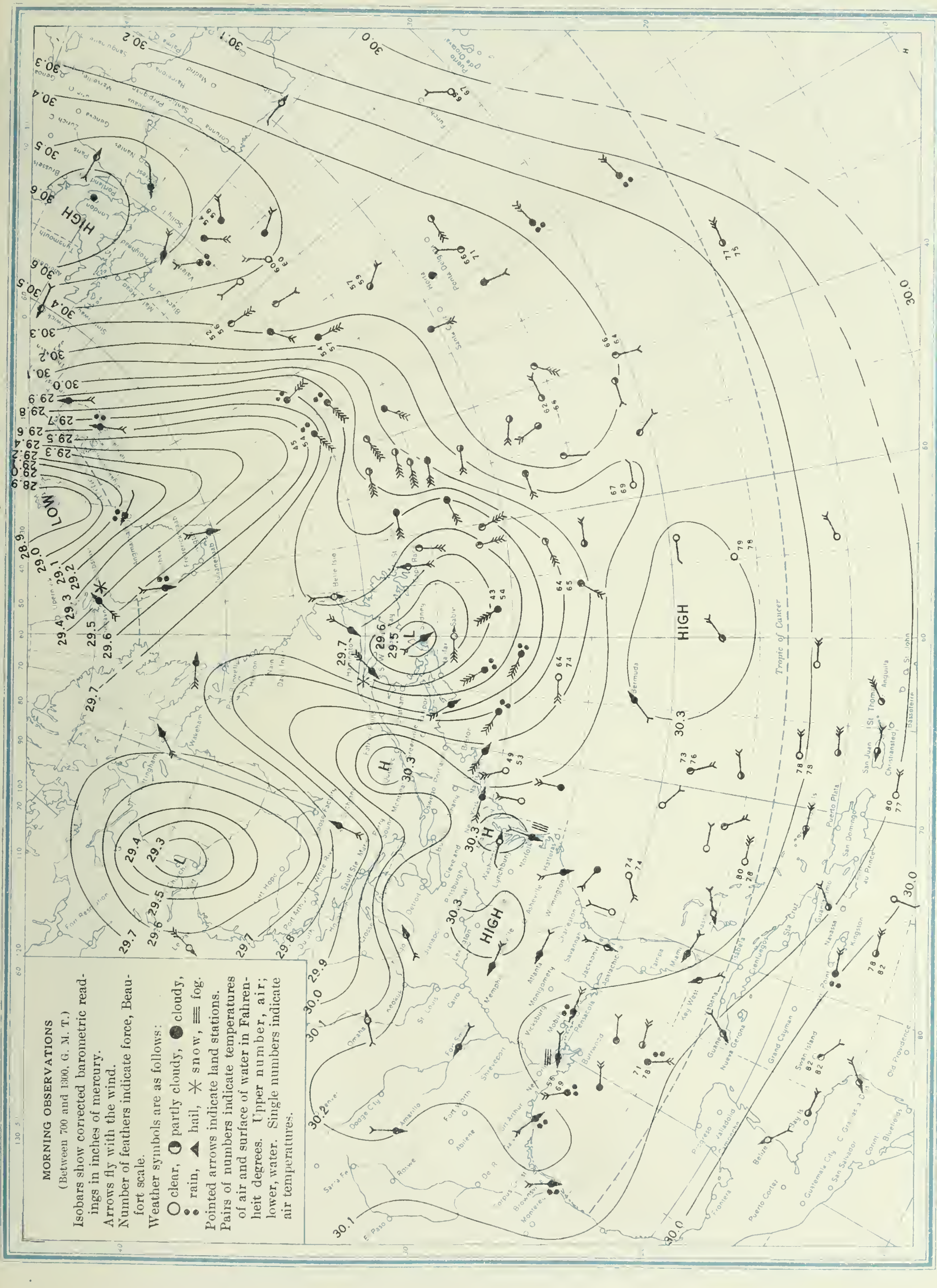
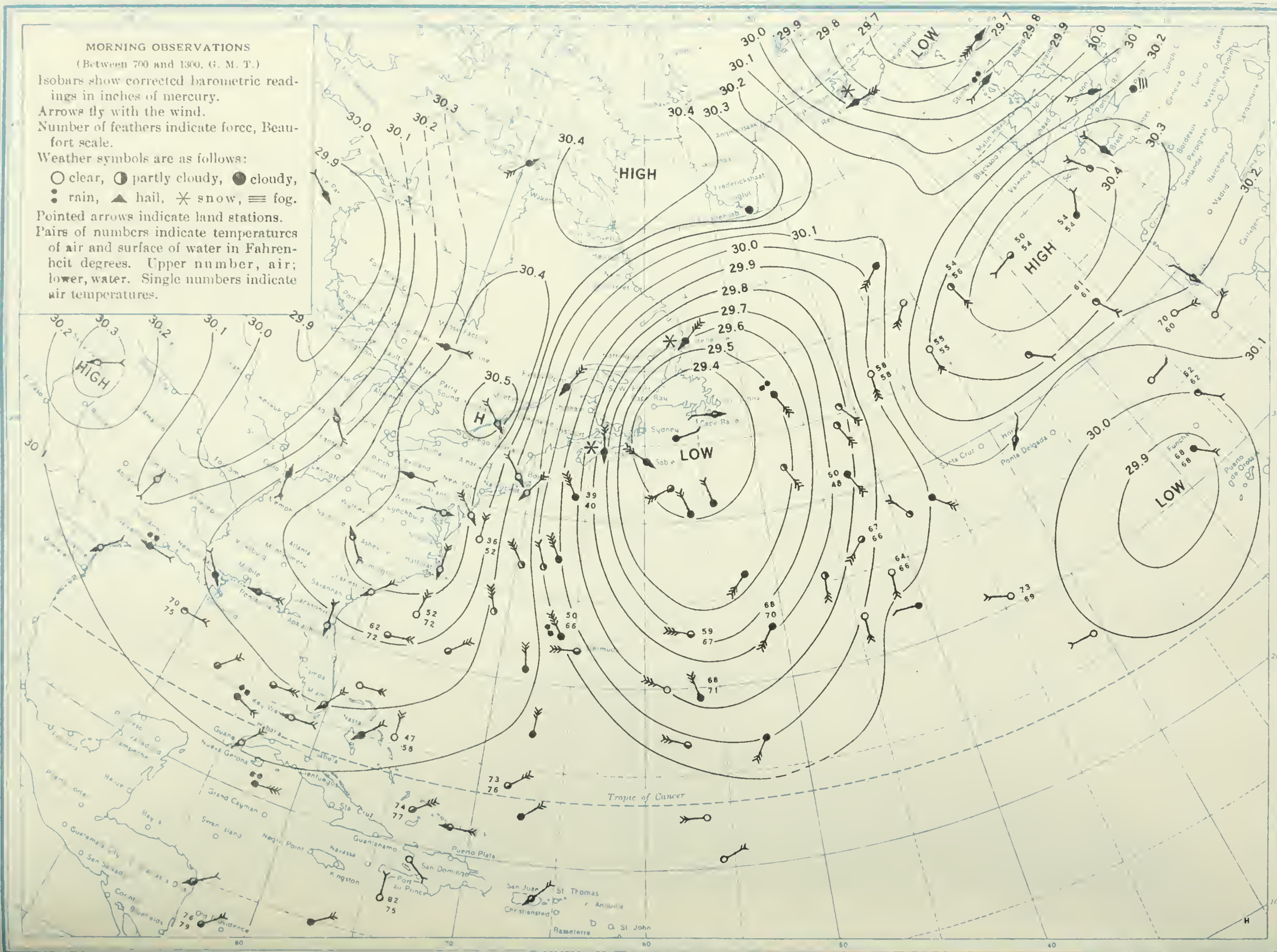


Chart XI. Weather Map of North Atlantic Ocean, December 27, 1931

(Plotted from the Weather Bureau Northern Hemisphere Chart)



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